Chapter 5. IN-VALLEY MANAGEMENT OPTIONS AND PLANNING ALTERNATIVES

This chapter reports the results of analyses made by use of the planning process described in Chapter 4. The analyses are a necessary transition step toward laying out a recommended plan.

First, an estimate is presented of the future drainage problem and its consequences, assuming present trends continue and no coordinated and comprehensive action is taken by local, State, and Federal entities to solve drainage problems. This is called the Future-Without Alternative, and it is useful as a basis for comparison with planned actions for the future. Next, planning building blocks, called "options," are described. These can be fitted together in compatible mixes to form alternatives to the future-without alternative. Finally, three planning alternatives that emphasize different strategies are formulated and displayed as a basis for designing the recommended plan presented in Chapter 6.

THE FUTURE-WITHOUT ALTERNATIVE

The future-without alternative represents conditions that could develop in the valley if coordinated, comprehensive actions are not taken by local, State, and Federal entities to solve drainage and drainage-related problems. The President's Council on Environmental Quality requires that all Federal planning studies include a future-without alternative as part of project planning. The future-without alternative is intended to give planners and the public a common ground from which to judge the need for actions to change present trends. It is also a baseline against which the economic, environmental, social, institutional, and physical effects of planned actions may be measured to determine their positive or negative effects.

Development of the future-without alternative involves: (1) Describing a general, overall theme for the future in the valley; (2) developing a set of assumptions about economic, environmental, social, institutional, and physical conditions in the valley and projecting trends; and (3) quantifying the effect of these assumptions on the planning subareas.

The Overall Theme

In February and March 1987, the San Joaquin Valley Drainage Program conducted multi-disciplinary workshops designed to develop future scenarios of conditions that would likely prevail in the absence of a coordinated, comprehensive plan to solve the valley's drainage and drainage-related problems. Participants included valley farmers, wildlife refuge managers, water district managers, academicians and researchers, and Federal and State agency personnel. The groups discussed major themes and trends that were forcing changes in agricultural drainage-related conditions in the valley. They concluded that central themes shaping future trends were related primarily to the public's desire to protect fish and wildlife and to sustain agriculture in the valley (SJVDP, 1987).

Assumptions About the Future

Assumptions regarding future economic, environmental, social, institutional, and physical conditions and trends in the valley are summarized below. Two overriding assumptions are that no catastrophic natural events and no major changes in the national political, economic, or social climate would occur.

More specific assumptions and trends are:

- The present trend toward less Federal government participation and more privatization would continue. Government expenditures for major water projects would continue to decline, and Federal farm subsidies would be reduced gradually. More responsibility for natural resources management would fall on State and local governments and the private sector.
- Public pressure for environmental protection would increase, leading to more stringent environmental regulations, and increased governmental enforcement of those regulations. This could result in user charges, taxes, and penalties to aid environmental protection.
- Agricultural economic conditions would remain relatively stable. The United States, the State of California, and the San Joaquin Valley would compete favorably in world agricultural markets. Irrigated agriculture in the valley would be able to afford and install some drainage improvements but would not be able to do so uniformly, and some land would be removed from production as a result of drainage and related problems.
- California's population would continue to grow, increasing the urbanization of the San Joaquin Valley, including westside agricultural lands, more of which would be converted to urban, residential, commercial, and industrial uses (with their attendant transportation and communication needs). Air pollution, waste generation, and noise would increase.
- Importation of water to the study area would not be significantly increased.
- There would be a shift in the northern part of the valley from agricultural water use to urban uses.
- Existing public wildlife areas would be preserved and protected, but no new areas or water supplies would be developed. Wetlands acreage on both public and private wildlife areas would diminish as their intermittent water supplies disappeared.
- Overall, surface- and ground-water quality in the study area would continue to deteriorate.
- The land area adversely affected by a high ground-water table would increase. The shallow ground water would become more saline, and, as a result, agricultural land would be removed from production.

- Except for use of the San Joaquin River, in conformance with water-quality objectives, no drainage outlet from the valley would be provided.
- The rate of adoption of water conservation measures in drainage problem areas would increase.
- Independent and uncoordinated actions related to agricultural drainage would result in litigation, not only between agricultural and environmental interests but also among groups having similar interests.
- Piecemeal legislation and institutional change would add to the drainage problem, causing the range of choices for water, land, and fish and wildlife managers to narrow and bringing significantly higher costs to most concerned parties.

The Shape of the Future Under the Future-Without Alternative

The future-without alternative, as shaped by assumptions described in the previous section, is described here in terms of land-use change and assessments of the hydrologic, economic, fish and wildlife, public health, and social effects of that change.

Land-Use Change

Analysis of present trends toward change in the future hydrologic system of the western side provided estimates of irrigated land, land abandoned due to salinization, and land drained by 2000 and 2040 (Table 11). The main conclusion drawn from these estimates and from backup data compiled in the Drainage Program's technical reports is that the absence of a clear, comprehensive approach to drainage management would likely lead to soil salinization and the abandonment of about 460,000 acres of irrigated agricultural land by 2040. The result would be major losses in agricultural production.

Table 11. IRRIGATED LAND CHANGES UNDER THE FUTURE-WITHOUT ALTERNATIVE
In 1,000s of acres

SUBAREA	1990			2000				2040			
	Drained Area	Irrig-able Area	Irri-gated Area[1]	Drained Area	Aban-doned Lands[2]	Change to Urban Land Use	Irri-gated Area[3]	Drained Area	Aban-doned Lands[4]	Change to Urban Land Use	Irri-gated Area[3]
Northern	24	165	157	34	0	5	152	51	0	25	133
Grasslands	51	365	329	85	0	4	325	152	40	20	225
Westlands	5	640	576	50	28	0	551	49	140	5	446
Tulare	42	612	551	86	38	0	517	94	190	5	325
Kern	11	762	686	14	18	5	665	40	90	35	573
TOTAL	**133**	**2,544**	**2,299**	**269**	**84**	**14**	**2,210**	**386**	**460**	**90**	**1,802**

1 Irrigated area is 95% of the irrigable area in the Northern Subarea and 90% of all other subareas.
2 Calculated as 20 % of the 2040 abandoned land estimate, except Grasslands, where discharge to the river is expected to forestall salinization and resultant abandonment until after 2000.
3 Irrigated area is 90% of the difference between the irrigable area and the sum of the land abandoned and land changed to urban, except in the Northern Subarea where the factor is 95%.
4 Values based on WADE model analysis, using estimated 2040 area with water table less than 5 feet from ground surface, and present salinity and selenium concentrations in shallow ground water (0 to 20-foot depth).

By 2040, salinization of irrigated land could be expected to diminish the irrigated area by about 11 percent in the Grasslands Subarea, 22 percent in the Westlands Subarea, 31 percent in the Tulare Subarea, and 12 percent in the Kern Subarea. No irrigated land in the Northern Subarea would be affected.

Hydrologic Effects

A general reduction in irrigated agricultural water requirements is expected in areas with shallow ground water at or near 5 feet in depth. This could occur because of increasing contributions of a very high water table to evapotranspiration and abandonment of waterlogged lands. The shallow ground water would become more saline, as would overlying lands. On affected lands, this condition would change farming practices and selection of crops grown. Eventually, the value of the lands for irrigated agriculture would decline to a level that would force abandonment of the lands. Changes in land use within the study area, including conversion of irrigated lands to residential and commercial development, would also reduce irrigation deliveries.

Limited opportunities to dispose of drainage would gradually reduce water deliveries to the lands with rising soil salinity during the next 50 years. Estimated reductions of irrigable land areas and irrigation water requirements due to salinization, changes in land use, and a modest increase in irrigation application efficiencies are shown in Table 12.

The quality of water provided by the State and Federal water projects would not change significantly throughout the planning horizon. However, the water in crop root zones would become more saline and, in places, would become loaded with boron due to increased evaporation of water from a near-surface water table.

The present quantity of firm water supply available for wildlife management areas would probably diminish under the future-without alternative. In a normal year, firm water deliveries of 97,000 and 17,000 acre-feet are available, respectively, to wetlands within the Grasslands and Northern subareas. These amounts do not allow for any replacement of the selenium-contaminated drainage water used for wetland management.

Table 13 shows that the quantity of subsurface drainage would be expected to more than double the present level by 2040. These estimates reflect the effects of increasing on-farm source control measures to reduce deep percolation by an average of 0.20 acre-foot per acre in the Grasslands, Westlands, and Kern subareas and 0.05 acre-foot per acre in the Tulare Subarea. The estimate reflects no reduction in the Northern Subarea. In contrast, the average target adopted for the Drainage Program's planning alternatives is 0.35 acre-foot per acre in the Grasslands, Westlands, and Kern subareas, and 0.20 acre-foot per acre in the Tulare Subarea, with no reduction in the Northern Subarea.

Table 12. CHANGE IN IRRIGABLE AREA AND WATER REQUIREMENT UNDER THE FUTURE-WITHOUT ALTERNATIVE

Subarea	Irrigable Area[1] (1,000s of acres)			Total Irrigation Water Requirement[2] (1,000s of acre-feet)		
	Present	2000	2040	Present	2000	2040
Northern	165	160	140	530	520	460
Grasslands	365	361	305	1,180	1,140	970
Westlands	640	612	495	1,580	1,470	1,190
Tulare	612	574	417	1,300	1,220	880
Kern	762	739	637	2,040	1,870	1,610
TOTAL	**2,544**	**2,446**	**1,994**	**6,630**	**6,220**	**5,110**

1 In any given year, about 90% of this area is actually being irrigated, except for the Northern Subarea, where 95% is irrigated..

2 The procedure used to estimate the water requirement is described in D.G. Swain (1990).

Table 13. ESTIMATED SUBSURFACE DRAINAGE VOLUME UNDER THE FUTURE-WITHOUT ALTERNATIVE In 1,000s of acre-feet

Subarea	Present	2000	2040
Northern	18	26	37
Grasslands	38	54	105
Westlands	4	28	27
Tulare	32	47	52
Kern	8	8	22
TOTAL	**100**	**163**	**243**

The present weighted average concentration of salts in drainage water estimated to occur in each of the water quality zones varies from about 1,000 to 25,000 parts per million total dissolved solids. Under future-without conditions, the quality of the shallow ground water would improve gradually in areas of high salinity where drainage is provided and salts are leached from soils. However, in undrained areas with a high water table, the lands may have become salinized before the quality of shallow ground-water had improved significantly.

Economic Effects

The future-without conditions were analyzed for 2040, and the agriculturally related economic impacts are compared to present conditions in Table 14. Overall, the future-without would exhibit a net decline in irrigated acreage, income, sales, and jobs. About 554,000 acres would be abandoned or converted to noncrop uses, with an associated loss of crop value of about $440 million per year. The negative impacts on retail sales in the surrounding communities would be about $63 million annually. Personal income in the study area would be reduced by over $123 million annually.

Table 14. REDUCTION IN RETAIL SALES, INCOME, AND EMPLOYMENT FROM PRESENT TO FUTURE-WITHOUT CONDITIONS, 1987-2040

Item	Subarea				Total
	Grasslands	Westlands	Tulare	Kern	
Reduction in irrigated crop area (1,000s of acres)	62	151	210	131	554
Lost crop value	42,747	130,344	175,452	92,712	441,255
Direct retail sales	1,555	4,743	6,385	3,374	16,057
Indirect and induced retail sales	4,545	13,903	18,804	9,913	47,165
Total retail sales	**6,100**	**18,646**	**25,189**	**13,287**	**63,222**
Direct personal income	5,362	16,532	22,637	11,859	56,390
Indirect and induced personal income	7,285	29,805	14,376	15,441	66,907
Total income	**12,647**	**46,337**	**37,013**	**27,300**	**123,297**
Direct employment	399	1,183	1,519	822	3,923
Indirect and induced employment	1,020	2,160	1,022	1,071	5,273
Total employment	**1,419**	**3,343**	**2,541**	**1,893**	**9,196**

Note: Crop value, retail sales, and income are in 1,000 (1990) dollars per year and employment is in person-years per year.

Employment projections indicate that total agricultural employment in the four subareas would fall by nearly 4,000 jobs. The loss of agricultural production would cause more than 5,000 jobs to be lost in the supporting industries and communities serving agriculture. Overall employment losses could reach nearly 9,200 jobs.

The secondary and induced impacts would be felt statewide, with the greatest experienced in the valley communities and the balance predominantly felt in the San Francisco Bay area and the Los Angeles basin.

This analysis does not take into account the value of resources freed after lands are abandoned. Depending on the assumptions concerning the reallocation of water and the fate of the lands abandoned, other positive values could be expected. Alternative uses for the abandoned or reallocated resources could be expected to exhibit some compensating income and employment characteristics.

The loss of fish and wildlife habitat and populations in the San Joaquin Valley associated with future-without conditions would mean less direct recreational use of these resources. This would result in regional economic impacts in the form of reduced retail sales, personal income, and employment. In addition, the value society receives from simply knowing that environmental resources in the valley exist and that the option exists to use these resources would be reduced under future-without conditions. No estimates have been made of the economic values and regional economic impacts for future-without conditions, compared to present conditions.

Other agricultural areas that produce similar crops could benefit when competitors abandon their lands. The net result of such a regional shift has not been analyzed. However, it is expected that the bulk of net acreage and crop reductions would occur in relatively salt-tolerant row and grain crops, such as cotton and wheat.

Clearly, a major reallocation of resources would occur. Water, land, and labor would be only part of the picture. The losses to the financial community and the local tax base would be substantial. Losses in land asset value could encourage a new round of investment at a lower cost. However, a net outmigration of investment capital would probably occur in heavily impacted valley communities.

Effects on Fish and Wildlife Resources

Without a firm supply of suitable quality water delivered when needed, the total acreage of healthy wetlands in the valley would continue to decline. At present, there are about 85,000 to 90,000 acres of seasonal and permanent wetlands in the valley. It is estimated that, by 2040, only about 55,000 acres (those with firm water supplies) would remain. Populations of migratory and resident wildlife species dependent on those scarce habitats would decline. Effects on populations of wintering migratory birds (waterfowl, shorebirds, and long-legged wading birds, for example) would probably be especially severe as birds crowded into ever-smaller areas of habitat, increasing the incidence and impact of avian diseases. Opportunities for such human uses of these wildlife resources as bird watching, nature study, and waterfowl hunting would diminish or even be prohibited.

Even with hazing and other similar efforts, evaporation ponds containing elevated concentrations of selenium, boron, arsenic, molybdenum, uranium, other trace elements, and salts would constitute an extremely serious contaminant hazard to wintering and resident populations of aquatic birds. Operation of toxic ponds could also pose contaminant hazards to endangered predators known to occur in the southern end of the valley (for example, the bald eagle, American peregrine falcon, and San Joaquin kit fox). The development and operation of expanded or new pond acreage would likely impact populations of several other endangered species. Because elevated concentrations of selenium were found in tissues of birds taken from some evaporation ponds, a public health warning was issued, advising hunters to limit or discontinue their consumption of waterbirds taken from those ponds. All these contaminant hazards would be compounded by the decreasing acreage of clean wetlands habitat.

Agroforestry plantations, developed to aid drainage management, would provide valuable new habitat for a variety of birds, mammals, and other species of wildlife, if the tree farms do not pose a contaminant hazard.

Water-quality objectives for the San Joaquin River basin adopted by the Central Valley Regional Water Quality Control Board still allow certain waterways to contain concentrations of selenium considered by some researchers to be toxic to wildlife. The actual effects on the fishery are unknown, due to a lack of toxicity studies.

Because of inadequate instream fishery flows from eastside tributaries to the San Joaquin River and high volumes of subsurface agricultural drainage water flows from the Grasslands area, upstream migrating adult salmon pass from the San Joaquin River into Mud and Salt Sloughs instead of the Merced River to spawn. This situation has prompted expensive efforts to trap and artificially spawn adult fish and transport the eggs to the Merced River Fish Facility for hatching and rearing. In a future-without scenario, this situation could be expected to continue indefinitely.

Several efforts have recently been initiated to address the inadequate instream fishery flows (for example, in the mainstem San Joaquin River between the Merced River and Friant Dam) and related environmental problems in the basin. Such efforts include the California Department of Water Resources' San Joaquin River Management Program, the U.S. Bureau of Reclamation's San Joaquin River Basin Resource Management Initiative, and litigation regarding renewal of 40-year water contracts from the Friant project. It is uncertain whether any of these efforts will provide flows in the mainstem San Joaquin River of adequate quantity and quality to support a viable fishery, including restoration of Chinook salmon runs.

In addition, loading of selenium and other drainage-related contaminants into the Bay-Delta ecosystem would continue under the future-without alternative. It is unknown what effects, if any, long-term loading of these systems with such trace elements would have on the health of the fishery, on other water-dependent wildlife, or on humans consuming such animals.

Public Health Effects

The greatest risk to public health from the lack of a coordinated action to solve the drainage problem is likely to arise from increased use of conventional evaporation ponds for disposal of agricultural drainage water. Where bioaccumulation of trace elements occurs through the aquatic food chain, consumption of contaminated game would increase human exposure to elevated concentrations of these elements. Decommissioning of evaporation ponds might also pose occupational hazards from inhalation of airborne contaminants.

Because ground- and surface-water quality in the valley will continue to deteriorate, potential human exposure to water contaminants will become greater. Future population growth and urban expansion projected for the San Joaquin Valley will bring people closer to all sources of agricultural drainage-water contaminants (air, soil, water, and biota) and thus reinforce the likelihood of adverse effects from exposure of such contaminants.

Social Effects

Farmland is expected to be abandoned more rapidly toward the end of the planning period. However, since the impacts would be spread over several decades, their effect upon farm operators, employees, and rural communities would permit adjustment that would moderate the cumulative social effects associated with the loss of productivity.

While land is being abandoned, the value and marketability of drainage-affected agricultural land would slowly stagnate, while uncertainty about the future would grow. Without an integrated regional solution, individual farmers would have increasing difficulty acquiring financing for farm operations and installation of drainage management facilities.

Patterns of land abandonment would likely be irregular, with farmers attempting to preserve the most productive lands for high-value crops and selecting less productive lands for on-farm drainage disposal. The remaining irrigated lands would be used more intensively as lands with drainage problems were abandoned. Over time, the cropping pattern in the approximate 1-million-acre drainage problem area would become less diverse, with production shifts toward less profitable salt-tolerant crops. Farmers with marginal technical capacity and financial resources would suffer the most severe consequences; many small and/or undercapitalized farm operations would go out of business.

Those who farm lands without drainage problems could acquire a competitive economic advantage over those who farm lands with high water tables and associated high salinity, by realizing increases in land value and profitability. Nevertheless, the total agricultural production (and associated agribusiness) in the San Joaquin Valley would likely decline significantly from present levels.

There would also be a significant conversion of farmland to alternative uses, either wildlife habitat or residential/commercial development. San Joaquin Valley towns within the drainage study area would become less dependent upon their traditional agricultural support base and more autonomous as fully developed small cities. Population expansion associated with the growth of valley communities would likely put greater pressures upon wildlife refuges and recreational lands.

The current level of cooperation among water districts in water management activities could deteriorate as drainage conditions worsened in the valley. As the value of the assessment base of farmland dropped due to lower land values, water districts would be less able to take action to resolve drainage problems. The smaller districts would be more adversely affected (at least five of them in the drainage study area could lose more than 50 percent of their assessment base through land abandonment). Some water management districts might be forced to merge and/or centralize operations to meet growers' needs and would probably not be capable of resolving drainage problems without considerable assistance from other agencies.

OPTIONS FOR DRAINAGE-WATER MANAGEMENT

The Drainage Program has identified a broad range of individual structural and nonstructural management options, which analyses show have potential for helping to solve subsurface agricultural drainage and related problems in the San Joaquin Valley. Some 80 options, classified into seven categories, were identified and described in the Program's *Preliminary Planning Alternatives* report of August 1989. The options are the basic building blocks of the alternative plans. However, no single option will achieve all the desired results. Several of them, fitted together into a coordinated, comprehensive plan for action, could be effective in managing drainage problems. The mix of options will have to be varied to accommodate local and regional differences in drainage problems and opportunities for solution. Different mixes of options are emphasized in the alternatives described later in this chapter. The options shown through analysis to be most useful in drainage problem management at this time are briefly discussed in the following sections.

Drainage-Water Source Control

A first step in solving valley drainage problems is to reduce the production of potential drainage water; that is, to control drainage production at the source. Source control options encompass a broad array of measures to apply irrigation water more efficiently and to manage land and water in ways that reduce the magnitude and adverse effects of drainage and drainage-related problems. Options included in the alternatives are:

- Water conservation:

  Improve existing irrigation practices and/or adopt new irrigation methods.

  Improve irrigation scheduling.

  Improve management of irrigation systems.

  Manage the water table to increase its contribution to crop evapotranspiration.

- Change in land use:

  Cease irrigation of lands that have high salinity and selenium concentrations in underlying shallow ground water and that are difficult to drain.

Each of the alternatives presented later in this chapter includes some degree of source control. Water conservation and retirement of lands from irrigated agriculture are discussed separately as drainage management plan components.

Ground-Water Management

In some parts of the principal study area, water in the semiconfined aquifer above the Corcoran Clay (Figure 4) is of suitable quality for direct application in irrigation.[1] This water occurs in both the Sierran sediments and the Coast Range alluvium parts of the aquifer. Where there is an adequate vertical hydraulic connection between waterlogged lands and this deeper, usable ground-water zone, pumping from the zone may be used to lower the water table. Planned application of pumped water as a substitute for a portion of the surface-water irrigation supply could bring the system into hydrologic balance and stabilize the water table at a lower depth. This would make part of the surface-water supply currently required for that area available for other uses.

Drainage-Water Treatment

Various drainage-water treatment processes have been investigated at several levels of development. The goal of these investigations has been to identify methods of removing trace elements of concern (mainly selenium) from drainage water.

These processes have not been investigated equally or developed to the same level of technology. A review of the capabilities and limitations of processes investigated was completed and is presented in Hanna, et al., 1990. A few, such as anaerobic-bacterial treatment, high-rate algal ponds, and ferrous hydroxide, have advanced beyond laboratory bench-scale research. However, investigations of even these methods are incomplete, and more work with larger scale "pilot" or "prototype" plants is needed to establish technical performance and reliable cost estimates. Moreover, there has been no substantial operational experience with any drainage-water treatment process. The most promising new processes for selenium removal are biological processes. Of these, research is most advanced on the anaerobic-bacterial process. Research and demonstration are continuing on the physical and chemical removal of selenium, such as the work being done on iron filings at Panoche Water District, and this procedure should be pursued further. Reverse osmosis and other desalting methods are proven but high-cost methods.

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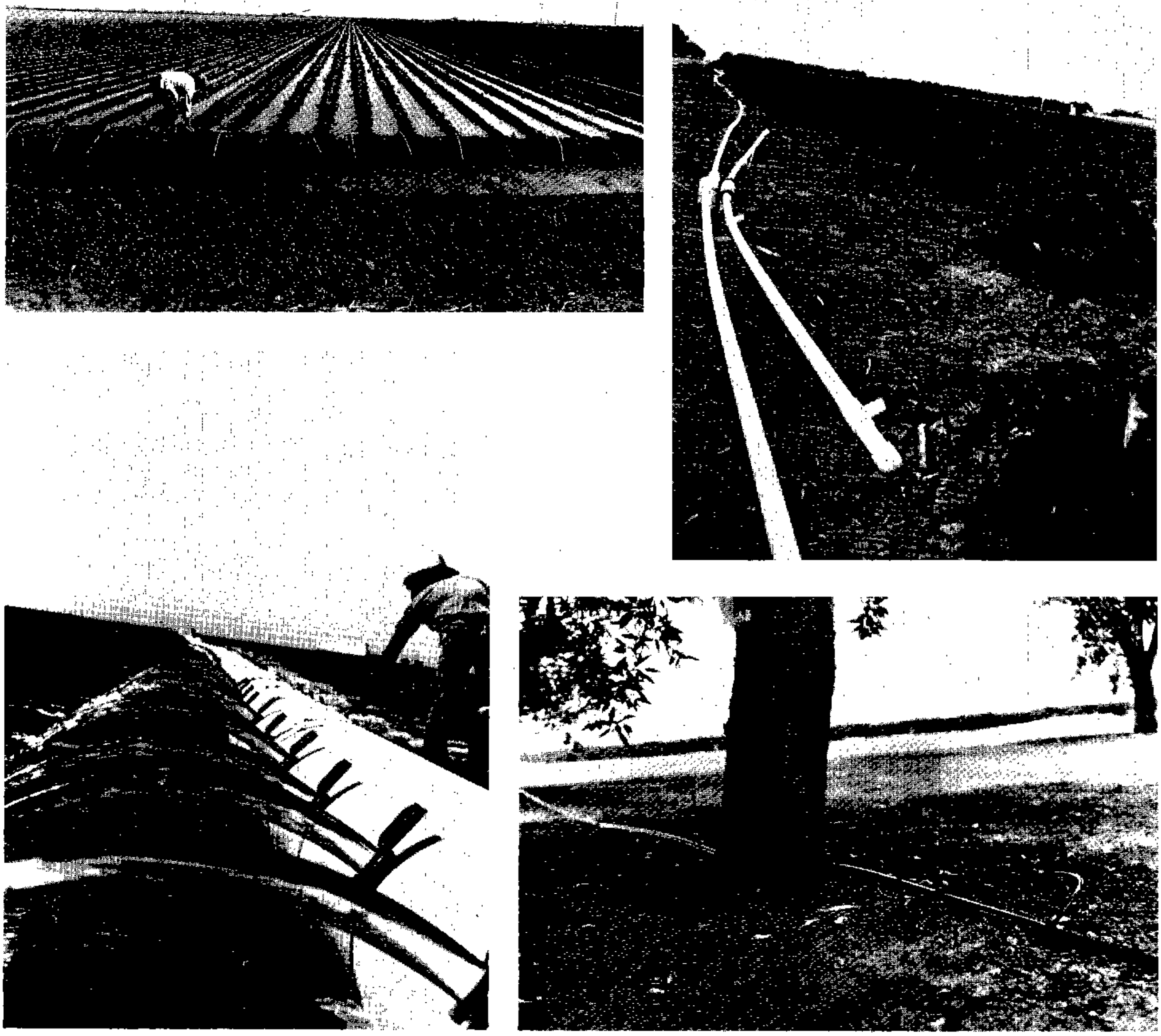
[1] Blending with other irrigation water supplies to make possible the use of saline ground water on crops normally grown in the drainage problem area was not included as an alternative plan component.



Irrigation water can be applied more efficiently by using shortened furrow lengths (upper left), drip systems (upper right), gated pipe (lower left), and microsprinklers (lower right).

Treatment of drainage water is not included in the alternatives because the uncertainties of their effectiveness and/or their high cost make investment in them a fiscal risk at this time. However, the Drainage Program recommends additional study of treatment processes because of their long-term potentials (see Chapter 1).

Drainage-Water Reuse

Of the various possible reuses of drainage water, irrigation (including salt-tolerant trees and halophytes), fish and wildlife habitat water supply, and solar ponds for energy production appear to have the greatest promise at this time. The options considered for the alternatives are:

- Reuse of subsurface drainage water for agriculture:

  Reuse on very salt-tolerant crops having an upper permissible limit of 2,500 ppm TDS in water supply; cotton (after plant emergence), for example.

  Reuse on salt-tolerant trees having an upper permissible limit of 10,000 ppm TDS in water supply; eucalyptus trees, for example.

  Reuse on halophytes having an upper permissible limit of 25,000 ppm TDS in water supply; atriplex, for example.

- Use of concentrated drainage water in solar ponds (from agricultural reuse options or from evaporation ponds) for energy production.
- Use of drainage water for fish and wildlife habitat when there is very low toxic risk.

Each alternative includes some amount of drainage-water reuse.

Drainage-Water Disposal

Drainage-water disposal options include: (1) Discharge to the San Joaquin River, with and without dilution; (2) discharge to evaporation ponds; (3) deep percolation into ground water; (4) injection into deep geologic formations; and (5) use for irrigation on the eastern side of the valley. The following are considered for inclusion in the alternatives at this time:

- Discharge to the San Joaquin River without dilution (including use of portions of the San Luis Drain to convey drainage water to treatment or disposal areas).
- Discharge to ponds to evaporate drainage water and concentrate dissolved constituents.
- Deep percolation into the semiconfined aquifer.

Westlands Water District continues to experiment with deep-well injection and, if successful, may use option (4), immediately above.

Fish and Wildlife Measures

Fish and wildlife measures have been developed that address the Drainage Program's goal to "protect, restore, and to the extent practicable improve fish and wildlife resources of the San Joaquin Valley." Options included here are those which could be undertaken in concert with other options to address drainage-related problems. Options for improvement of fish and wildlife resources are discussed in the Drainage Program's *Preliminary Planning Alternatives* report. Options considered for inclusion in the alternatives at this time are:

- Protection (in addition to the assumed enforcement of water-quality, wildlife, and other environmental laws):

  Modify evaporation pond design, construction, operation, and monitoring so that ponds are bird-safe or bird-free.

  Develop definite plans for evaporation pond closure when closure appears to be necessary or inevitable.

  Provide alternative habitat (including adequate water supplies) near evaporation ponds that require hazing because they are unsafe for birds.

- Restoration:

  Flood and flush habitat with freshwater.

  Manage soil and vegetation to decontaminate wildlife habitat.

- Substitute water supplies for fish and wildlife to replace contaminated drainage water. Substitute water would also improve protection and assist restoration. (These options must include modifications of existing supply or drainage systems to allow delivery of water to fish and wildlife areas directly, or by exchange arrangements.)

  Use water saved from source-control options (that is, on-farm water conservation and/or land retirement).

  Use wetland areas to seasonally store agricultural water supplies for release during April and May to improve fish habitat in the San Joaquin River.

  Use ground water produced by ground-water management options.

  Use nontoxic drainage water to produce saline wetlands.

Institutional Changes

Growers and private and public fish and wildlife managers operate within a framework of Federal, State, and local laws, policies, and practices. Some changes in the existing institutional framework may help solve drainage problems, directly or indirectly, by allowing implementation of plan components that otherwise might not be undertaken. The options listed here appear to be those most likely to be used in helping solve the drainage problem. A long list of potential institutional changes was provided and discussed in the Drainage Program's *Preliminary Planning Alternatives* report. Analysis of potential changes is provided in the Natural Heritage Institute report on institutional change (Thomas and Leighton-Schwartz, 1990). The primary options being considered are:

- Use of tiered irrigation water pricing, or other types of financial incentives, by water districts, the Central Valley Project, or the State Water Project.
- Drainage contribution surcharge on irrigation water.
- Modification of water-transfer and water-marketing policy and laws.
- Formation of regional drainage management entities that might be structured as special districts, joint powers authorities, or nonprofit mutual benefit cooperatives.

Evaluation of Options

Before options are used in alternatives, it is necessary to: (1) Determine the geographical applicability of the options, and (2) evaluate their cost, performance, and impacts. The shallow ground water quality zones shown in Figure 18 are the units used for evaluation.

Options are applied within the framework of objectives and standards shown in Table 7. The applicability of drainage management options to each of the drainage water quality zones, under either performance Level A or B, is displayed in Tables 15 and 16, respectively. Source control is applicable in every area. Discharge of drainage water to the San Joaquin River is applicable in the Northern Subarea and in two areas of the Grasslands Subarea. Salt-tolerant trees can be grown to transpire drainage water in 10 of the 16 areas. Trees cannot be grown in the other six areas because drainage water from field crops (water supply for trees) will exceed 10,000 ppm total dissolved solids (salt). Growing extremely salt-tolerant plants, such as saltbush, is not precluded in any area. Table 15 shows that, under performance Level A, land retirement may be applicable in some shallow ground-water areas where dissolved selenium is above 200 ppm. Table 16 shows that, under performance Level B, much more area is candidate for retirement when the criterion is lowered to 50 ppb. Existing evaporation ponds may be continued under both A and B performance levels, but only if they are bird-safe or can be made bird-free. The assumed safe level of selenium concentration for Levels A and B are 5 ppb and 2 ppb, respectively. In the ground-water management option, water may be pumped from the semiconfined aquifer when the thicknesses of suitable aquifer materials exceed 100 feet (Level A) or 200 feet (Level B) and the quality of the water produced is suitable for irrigation.

The results of an evaluation of the options considered effective and available are presented in Table 17. The evaluation is based on uncertainty analyses, economic analyses, and standard impact assessment techniques.

In addition to the restraints provided by the planning objectives, criteria, and standards given in Table 7, the evaluation of options in Table 17 should shape the extent to which a given option can be used in an alternative. Table 17 indicates that virtually all options have some limitations or produce an adverse effect on an important parameter of interest; for example, fish and wildlife, the economy, or the local community. Conversely, each option shows characteristics and effects beneficial to some interests. Judgment has to be exercised in determining the emphasis to place on a given option, considering the balance of effects. The lowest-net-cost option is sought, but not at the expense of significant risk to other interests.

The evaluation reveals that, although some options are cost-effective, certain risks must be acknowledged. For example, the feasibility of discharge to the San Joaquin River might be affected significantly by possible future changes in water-quality regulations. Similarly, reuse might be affected by significant adverse effects on wildlife. In contrast, the risks of reuse of drainage water are less than the risks of evaporation ponds, and reuse has a comparative cost advantage. (Measures considered promising to make evaporation ponds bird-free or bird-safe are included in cost estimates.) Therefore, it is concluded that, comparatively, use of evaporation ponds should be minimized and reuse maximized.

Table 15. APPLICABILITY OF DRAINAGE MANAGEMENT OPTIONS
LEVEL "A" PERFORMANCE STANDARDS

Subareas and Water Quality Zones	Drainage Source Control	San Joaquin River Discharge[1]	Salt-Tolerant Trees	Halo-phytes	Land Retirement[2]	Existing Evaporation Ponds	New Evaporation Ponds[3]	Ground Water Management[4]
Grasslands								
A	X	Y(15.5k AF)	X	X	Y(37.4k Ac.)	Y(0.1k Ac.)	NA(>5 ppb Se)	Y(25k Ac.)
B	X	Y(4.0k AF)	X	X	NA(<200 ppb Se)	NA	X	Y(51k Ac.)
C	NR	X	NR	NR	NR	NR	NR	NR
D[5]	NR-W	NR-R	NR-W	NR-W	NR-W	NR-W	NR-W	NR-W
Westlands								
A	X	NA	X	X	Y(7.6k Ac.)	NA	NA(>5 ppb Se)	Y(9k Ac.)
B	X	NA	NA(>10k ppm TDS)	X	Y(7.0k Ac.)	Y(0.1k Ac.)	NA(>5 ppb Se)	NA(<100 ft. thick)
C	X	NA	X	X	NA(<200 ppb Se)	NA	NA(>5 ppb Se)	Y(69k Ac.)
D	X	NA	X	X	NA(<200 ppb Se)	Y(0.4k Ac.)	NA(>5 ppb Se)	Y(43k Ac.)
Tulare								
A	X	NA	X	X	NA(<200 ppb Se)	Y(0.5k Ac.)	X	Y(34k Ac.)
B	X	NA	NA(>10k ppm TDS)	X	NA(<200 ppb Se)	Y(3.6k Ac.)	NA(>5 ppb Se)	NA(<100 ft. thick)
C	X	NA	X	X	NA(<200 ppb Se)	Y(0.2k Ac.)	NA(>5 ppb Se)	NA(<100 ft. thick)
D	X	NA	NA(>10k ppm TDS)	X	NA(<200 ppb Se)	Y(0.3k Ac.)	NA(>5 ppb Se)	Y(38k Ac.)
E	X	NA	X	X	NA(<200 ppb Se)	Y(0.3k Ac.)	X	Y(100k Ac.)
Kern								
A	X	NA	NA(>10k ppm TDS)	X	Y(2.2 Ac.)	Y(1.3k Ac.)	NA(>5 ppb Se)	NA(<100 ft. thick)
B	X	NA	NA(>10k ppm TDS)	X	NA(<200 ppb Se)	NA	NA(>5 ppb Se)	NA(<100 ft. thick)
C	X	NA	X	X	NA(<200 ppb Se)	Y(0.2k Ac.)	X	NA(<100 ft. thick)
D	X	NA	NA(>10k ppm TDS)	X	Y(0.9k Ac.)	Y(0.2k Ac.)	NA(>5 ppb Se)	NA(<100 ft. thick)

1 Applicability of option depends on the selenium criterion (mean monthly concentration of 8 ppb) and a critical water year hydrology (for example, 1986-87) for San Joaquin River near Newman. Selenium load is expected to decrease up to 50% by 2040 as a result of the gradual removal of selenium from the shallow ground water and soils due to the leaching process.

2 The selenium concentration of 200 ppb in the shallow ground water was used to select lands on which irrigated agriculture would be discontinued.

3 New evaporation ponds can be used when drainage water selenium concentration exceeds 5 ppb and is ≤50 ppb only if ponds can be made bird-safe or bird-free. Measures necessary to make ponds bird-free will include alternative habitat with an adequate firm water supply.

4 Option limited by the aquifer thickness and quality of the ground water (less than 1,250 ppm TDS).

5 Managed wildlife wetland area.

X Option is applicable without any limitation in its application.

Y Option is applicable but limited to the quantities and units included in the parentheses.

NA Option not applicable because it fails to meet the performance standard in parentheses (see Table 7) or not physically available in the instances of discharge to the San Joaquin River.

NR Option not suggested because increased conservation with resulting increased salinity will reduce the likelihood that drainage water can be used for wetland habitat.

NR-W Option is not applicable since shallow ground water within wetlands is not a problem; it benefits waterfowl.

Table 16. APPLICABILITY OF DRAINAGE MANAGEMENT OPTIONS
LEVEL "B" PERFORMANCE STANDARDS

Subareas and Water Quality Zones	Drainage Source Control	San Joaquin River Discharge[1]	Salt-Tolerant Trees	Halo-phytes	Land Retirement[2]	Existing Evaporation Ponds	New Evaporation Ponds[3]	Ground Water Management[4]
Grasslands								
A	X	Y(4.5k AF)	X	X	Y(90.0k Ac.)	Y(0.1k Ac.)	NA(>5 ppb Se)	Y(17k Ac.)
B	X	Y(4.0k AF)	X	X	Y(0.3k Ac.)	NA	X	Y(16k Ac.)
C	NR	X	NR	NR	NR	NR	NR	NR
D[5]	NR-W	NR-R	NR-W	NR-W	NR-W	NR-W	NR-W	NR-W
Westlands								
A	X	NA	X	X	Y(23.2k Ac.)	NA	NA(>2 ppb Se)	NA(<200 ft. thick)
B	X	NA	NA(>10k ppm TDS)	X	Y(39.4k Ac.)	Y(0.1k Ac.)	NA(>2 ppb Se)	NA(<200 ft. thick)
C	X	NA	X	X	Y(57.9k Ac.)	NA	NA(>2 ppb Se)	Y(54k Ac.)
D	X	NA	X	X	NA(<50 ppb Se)	Y(0.4k Ac.)	NA(>2 ppb Se)	Y(31k Ac.)
Tulare								
A	X	NA	X	X	NA(<50 ppb Se)	Y(0.5k Ac.)	X	Y(21k Ac.)
B	X	NA	NA(>10k ppm TDS)	X	NA(<50 ppb Se)	Y(3.6k Ac.)	NA(>2 ppb Se)	NA(<200 ft. thick)
C	X	NA	X	X	NA(<50 ppb Se)	Y(0.2k Ac.)	NA(>2 ppb Se)	NA(<200 ft. thick)
D	X	NA	NA(>10k ppm TDS)	X	NA(<50 ppb Se)	Y(0.3k Ac.)	NA(>2 ppb Se)	Y(33k Ac.)
E	X	NA	X	X	NA(<50 ppb Se)	Y(0.3k Ac.)	X	Y(95k Ac.)
Kern								
A	X	NA	NA(>10k ppm TDS)	X	Y(219.5 Ac.)	Y(1.3k Ac.)	NA(>2 ppb Se)	NA(<200 ft. thick)
B	X	NA	NA(>10k ppm TDS)	X	NA(<50 ppb Se)	NA	NA(>2 ppb Se)	NA(<200 ft. thick)
C	X	NA	X	X	NA(<50 ppb Se)	Y(0.2k Ac.)	X	NA(<200 ft. thick)
D	X	NA	NA(>10k ppm TDS)	X	Y(23.6k Ac.)	Y(0.2k Ac.)	NA(>2 ppb Se)	NA(<200 ft. thick)

1 Applicability of option depends on the selenium criterion (mean monthly concentration of 2 ppb) and a critical water year hydrology (for example, 1986-87) for San Joaquin River near Newman. Selenium load is expected to decrease up to 50% by 2040 as a result of the removal of salts from the shallow ground water and soils due to the leaching process.

2 The selenium concentration of 50 ppb in the shallow ground water was used to select lands on which irrigated agriculture would be discontinued.

3 New evaporation ponds can be used when drainage water selenium concentration exceeds 2 ppb and is ≤50 ppb only if ponds can be made bird-safe or bird-free. Measures necessary to make ponds bird-free will include alternative habitat with an adequate firm water supply.

4 Option limited by the aquifer thickness and quality of the ground water (less than 1,250 ppm TDS).

5 Managed wildlife wetland area.

X Option is applicable without any limitation in its application.

Y Option is applicable but limited to the quantities and units included in the parentheses.

NA Option not applicable because it fails to meet the performance standard in parentheses (see Table 7) or is not physically available in the instances of discharge to the San Joaquin River.

NR Option not suggested because increased conservation with resulting increased salinity will reduce the likelihood that drainage water can be used for wetland habitat.

NR-W Option is not applicable since shallow ground water within wetlands is not a problem; it benefits waterfowl.

Table 17

SUMMARY EVALUATION OF OPTIONS CONSIDERED FOR DRAINAGE MANAGEMENT ALTERNATIVES[1]

Option	Annual Cost/ Acre of Land Served	Remarks on Costs	Engineering (Physical) Feasibility	Social Effects	Institutional	Effects on Environment[3] and Public Health	Agriculture	Fish and Wildlife	Economic
Source control (on-farm reduction of applied water)	$60	Costs based on currently available methods to reduce irrigation water application.	(+) Available and proven technology; (0) would solve only part of problem. Some deep percolation would continue.	(+) Enhances local control; (+) spinoff advantages in more trained personnel.	(+) Simplicity (means are available); (0) depends on acceptance by private sector.	(+) Reduces risk of insect or vector problem; (0) may increase concentration of dissolved constituents in receiving waters.	(+) Increases overall efficiency of irrigated farming and may increase production; (-) generally requires additional economic and labor input.	(+) Frees water that could be reallocated for fish and wildlife.	(+) Lowest cost drainage management method available to grower.
Reuse: salt-tolerant crops, trees, halophytes[2]	$150-160	Includes evaporation ponds for final disposal. Total costs are reduced by $45/ton of wood fiber.	(+) Proven technology, although yet to be demonstrated at scale needed; (-) complex operation requiring on-farm changes; (0) needs disposal process; e.g., evaporation ponds, to complete process.	(0) Raises skill requirements for farm labor; (-) possible increasing commitment to salt-tolerant tree monoculture.	(0) Need to implement on large scale probably invites more government involvement.	(-) Adverse air impact possible if wood fiber used in valley for cogeneration of power; (+)tree-growing would benefit air quality through consumption of CO_2 and production of O_2.	(-) Trees and shrubs would not yield a net profit as alternate crops; (0)may allow some on-farm management of drainage water.	(0) Increases terrestrial habitat, but may create new contaminant hazards.	(+) Could produce substantial benefits from harvested wood, but value of shrubs uncertain.
Ground water management[2]	$160-185	Based on 200-gpm wells on ½-mile grid. Total costs lowered by $50/AF value of water produced.	(0) Proven technology, but no operational experience for this purpose.	(0) Requires voluntary compliance or imposed control.	(-) May require change in laws or their administration; litigation likely on effect	(-) Could accelerate degradation of potential and existing water supplies.	(+) Provides additional alternate water supply during drought; (-) during wet years pumping is still required.	(+) Produces water that may be adequate in quality and could be made available for fish and wildlife.	(0) Relatively expensive, but provides water supply; (-) accelerates degradation of water, making leaching more expensive.

Table 17 (continued)

SUMMARY EVALUATION OF OPTIONS CONSIDERED FOR DRAINAGE MANAGEMENT ALTERNATIVES[1]

Option	Annual Cost/ Acre of Land Served	Remarks on Costs	Engineering (Physical) Feasibility	Social Effects	Institutional	Effects on Environment[3] and Public Health	Agriculture	Fish and Wildlife	Economic
Discharge through San Luis Drain to San Joaquin River[2]	$120	Costs include cleaning, extending and maintaining part of San Luis Drain chiefly for Grasslands drainage problem area A.	(+) Simple but could require many years to implement, depending on environmental regulations, funding, and time requirements.	(0) Trends toward regional management of drainage; (-) likely objection by downstream water users despite water quality objectives being met.	(0) See "Social Effect" column; (-) objections from other regions are likely.	(+) Minimizes risks of consuming selenium from fish and wildlife taken in Grasslands; (-) some occupational exposure possible during cleanup and disposal of 60–100 cu yd of sediment.	(-) Conceptually effective, but entities dependent on this service could be jeopardized by any shift from regulations on contaminant concentration to regulations on load; (+) achieves salt balance.	(+) Drainage water bypassing sloughs and wetlands would provide additional protection. (Receiving water quality objectives would have to be met.)	(0) Cost to rehabilitate drain may be offset by benefit of providing drainage service.
Evaporation ponds: existing, new, and accelerated[2]	$180-300	Costs rise as inflow selenium increases; cost of construction and operation of alternate wetland habitat included. Closure or solid waste disposal is not included.	(0) Some aspects require technology now under development and a careful integration of ponds into total drainage system.	(0) Raises skill needs for pond operators.	(-) Uncertainty about extent of implementation of federal and state laws.	(-) Some existing ponds contaminate wildlife with selenium to unsafe levels (as game); (-) unless well-managed and with applications of emerging technologies, ponds will be hazardous; (-) long-term problem of disposal of toxic precipitates; (-) possible occupational hazard.	(+) Method allows a range of size of operations; only single, effective means of disposal now available to some lands; (-) becoming more costly and difficult to meet environmental objectives.	(-) Some existing ponds produce significant adverse effects; (0) existing and new ponds would have to be bird-safe or bird-free; (0) one-for-one alternative habitat could be protective.	(-) May be very high cost if selenium concentrations are high. May not be affordable.
Land retirement	$170	Estimated fair market value of $1,500/ac for problem land and $20/ac/yr land maintainance cost.	(+) Simple; (0) requires some decommissioning of facilities.	(0) to (-) Impacts on communities depend on amount of land retired and where freed water is used.	(0) May require new institutional arrangements; (-) repayment of federal and state water contracts.	(-) Eliminates any onsite hazards associated with drainage water and its problem solution, assuming alternate land use and management are not a problem.	(-) Lands lost for agricultural production, perhaps permanently. (+) Frees water that could be reallocated to agricultural use in water-short areas.	(+) Frees water that could be reallocated for fish and wildlife; (0) reuse of retired land as wildlife habitat is unproven.	(+) Requires only willing buyer and seller; (-) on economy, unless water remains in impacted area; (+) water in other uses could increase in value.

Table 17 (continued)

SUMMARY EVALUATION OF OPTIONS CONSIDERED FOR DRAINAGE MANAGEMENT ALTERNATIVES[1]

Option	Annual Cost/Acre of Land Served	Remarks on Costs	Engineering (Physical) Feasibility	Social Effects	Institutional	Effects on Environment[5] and Public Health	Agriculture	Fish and Wildlife	Economic
Biological treatment[2] (10-mgd plant)	$250	Estimates omit cost of sludge disposal. No cost reduction for byproduct recovery.	(0) Process works at small pilot scale but cannot meet water quality objectives without dilution; (-) needs field demonstration of pilot plant.	(0) Raises skill requirements for farm labor and new service.	(0) Tends to build case for regional management of drainage.	(+) Assuming proper design, operation, and control of hazards, similar to existing municipal sewage treatment plants.	(+) Could be highly beneficial to agriculture, if costs could be lowered.	(+) Toxicants would be removed and segregated; (0) or (-) if performance level requires diluting with fresh water.	(+) Effective toxicant removal could produce byproducts that would enhance economy; (-) may be unaffordably expensive.
Discharge directly to San Joaquin River[3]	$60	Costs are for on-farm tile drains, plus water control facilities required to bypass or protect wetlands.	(0) Requires more effective monitoring of nonpoint sources; (+) simple to build.	(0) Raises skill needs and tends to support concept of regional mangement of drainage.	(0) Could be construed as preferred right to drainage held by exchange contractors, similar to riparian rights for water supply.	(0) Selenium standards would be met; (0) boron may be a limiting factor in the river.	(-) Conceptually effective, but dependend entities could be jeopardized by shifts from regulations on contaminant concentration to those on load; (+) maintains salt balance.	(0) or (+) If controlled and monitored appropriately; otherwise, (-).	(-) Could adversely affect downstream water users if selenium and/or boron (temporarily) became excessive.
Provision of water to fish and wildlife[4]	Assessment incomplete		(0) Requires full suite of planning, funding, design, and building for some areas; (+) other areas could be served immediately.	(+) Enhances recreation and variety and general liveability of local areas.	(+) Progress in this direction would lessen threats of litigation and improve the image of agriculture.	(+) Improved water conditions will increase stability of ecosystems and lessen public health risks.	(-) If seen as a competion for water; (+) possible balancing effects if increased water draws birds away from evaporation ponds.	(+) Meets some needs for protection, restoration, and substitute water supply.	(+) Improve resources valued by Californians; (+) improve hunting, fishing, and other activities.

1 Guide to ratings entered on evaluation sheet: (+) = potential beneficial effect, enhancing interests implied by column heading; (-) = potential negative effect, adverse to interests implied; (0) = neutral, or positive and negative aspects counterbalance.
2 Source control is included within the costs shown as an initial step in application of this component.
3 Able to drain directly to San Joaquin River because of low concentrations of selenium in water service area of exchange contractors.
4 This item pertains to water-supply deficit due to drainage-related causes.
5 Includes state water-quality objectives.

PLANNING ALTERNATIVES

Three planning alternatives were formulated that emphasize: (1) The conservation and reuse of agricultural water, (2) the extraction of irrigable water from deep within the semiconfined aquifer to lower the near-surface water table in waterlogged land areas, and (3) the retirement of irrigated agricultural lands overlying shallow ground water that contains greatly elevated concentrations of dissolved selenium. Two levels of performance, A and B, were applied to each alternative. These alternatives were devised to compare potential reduction in problem water volumes, if differing options for managing the drainage problem were emphasized. Four strategies involving major options that were employed in formulating the planning alternatives are discussed in the following sections.

Drainage Management Strategies Underlying the Alternatives

Four main strategies for management of drainage problems have emerged during the course of this study. These are source control, drainage water reuse, ground-water management, and land retirement. Each strategy is used to reduce problem water volumes in the three planning alternatives.

Source Control

The major source of recharge to the ground water system and subsequent production of drainage water is the portion of applied irrigation water that percolates past the crop root zone into the semiconfined aquifer. Some water must pass the root zone to leach salts and maintain soil productivity. Unnecessary deep percolation can be reduced mainly through better management of irrigation systems.

Current average deep percolation in the study area is estimated to vary from about 0.90 to 1.05 feet (Burt and Katen, 1988; D.G. Swain, 1990). Assuming 0.3 foot is the minimum amount necessary to achieve required salt leaching and is also the amount moving downward through the Corcoran Clay, nonbeneficial deep percolation contributes 0.60 to 0.75 foot annually to potential problem water.

Higher irrigation efficiencies leading to reduced deep percolation can be achieved by individual options or combinations of options. The most effective of these appear to be: (1) Improving management of irrigation systems, (2) improving present irrigation practices (for example, shortening furrows and using tailwater return systems, thus increasing uniformity of water application) and adopting new irrigation methods, and (3) improving irrigation scheduling. These and other options are discussed more fully in the Drainage Program's 1989 report, *Preliminary Planning Alternatives*.

Not all potential problem water is generated by deep percolation at a given site. Some lateral movement of water from upslope areas may also contribute to drainage problems downslope. This contribution varies considerably, depending upon local geologic and hydrologic conditions, but a drainage problem most often arises from practices and conditions at the site. Reduction of deep percolation, even in areas without present drainage problems, can help reduce the long-term regional drainage problem.

Drainage-Water Reuse

The concept of drainage-water reuse is shown in Figure 19. The objective is to reduce the volume of drainage water requiring ultimate disposal by reusing it on progressively more salt-tolerant crops. The volume of water would be reduced by evapotranspiration, with dissolved constituents such as salt, boron, and selenium becoming more concentrated and probably easier to manage in an environmentally safe manner. Volume reduction through reuse would substantially reduce disposal costs and treatment costs, if treatment became necessary.

The initial good-quality water supply would be used to grow high-value, salt-sensitive crops, such as vegetables. Drainage water captured in the tile drainage system under these lands would be collected and pumped into a local distribution system to become the water supply for a salt-tolerant field crop, such as cotton. (If this were not practicable, the drainage could go directly to trees.)

Drainage from these fields would become the water supply for salt-tolerant trees, such as eucalyptus. Trees would be used at this stage, not only because of their tolerance to salt, but also because they are capable of high transpiration rates (about 5 feet of water per year). Finally, drainage from the trees would be used on halophytes that grow in extremely saline conditions, such as atriplex or salt bush. Even halophytes have limits for total dissolved salts and certain other substances, such as boron. The levels of boron and total salinity of water in the root zone must be monitored and the fields drained to maintain growth.

At that stage of the reuse process, the extremely concentrated drainage water must be disposed of, or it could be stored in small evaporation ponds, treated to remove toxicants, or, when possible, injected into deep geologic formations. Water and salts from the evaporation ponds could also be used at solar-energy ponds or cogeneration facilities.

Figure 20 illustrates pond configurations that might be used as part of a drainage water management system. The *standard* evaporation pond shown would be similar to ponds traditionally used in the valley, except that it would be improved with steepened sides and greater depths to reduce wildlife food supplies and discourage wildlife use. In contrast to traditional ponds, the new standard pond would be smaller so that birds could be more effectively hazed from it to alternative safe wetland habitat (not shown on sketch) that would be provided in the vicinity.

The *nontoxic* evaporation pond would also provide safe wildlife habitat and would be designed for that purpose. The northern portion of the Tulare Subarea (Kings River Delta) appears to be an area in which drainage water could evaporate in ponds that would be safe for wildlife use.

The *accelerated rate* ponds would employ mechanical devices to increase the rate of evaporation. Used in a facility in El Paso, Texas, the device shown here reduced the volume of applied water by about 25 percent in one pass through the system. Use of an accelerated evaporation system greatly reduces pond area, but it increases the cost.

The *solar* pond shown would use very concentrated drainage water from either the standard or accelerated pond. The area covered by a solar pond would be small. This type of pond does not appear to attract birds. The value of the electrical energy generated would offset some of the total drainage system costs.

Figure 19. THE CONCEPT OF DRAINAGE-WATER REUSE

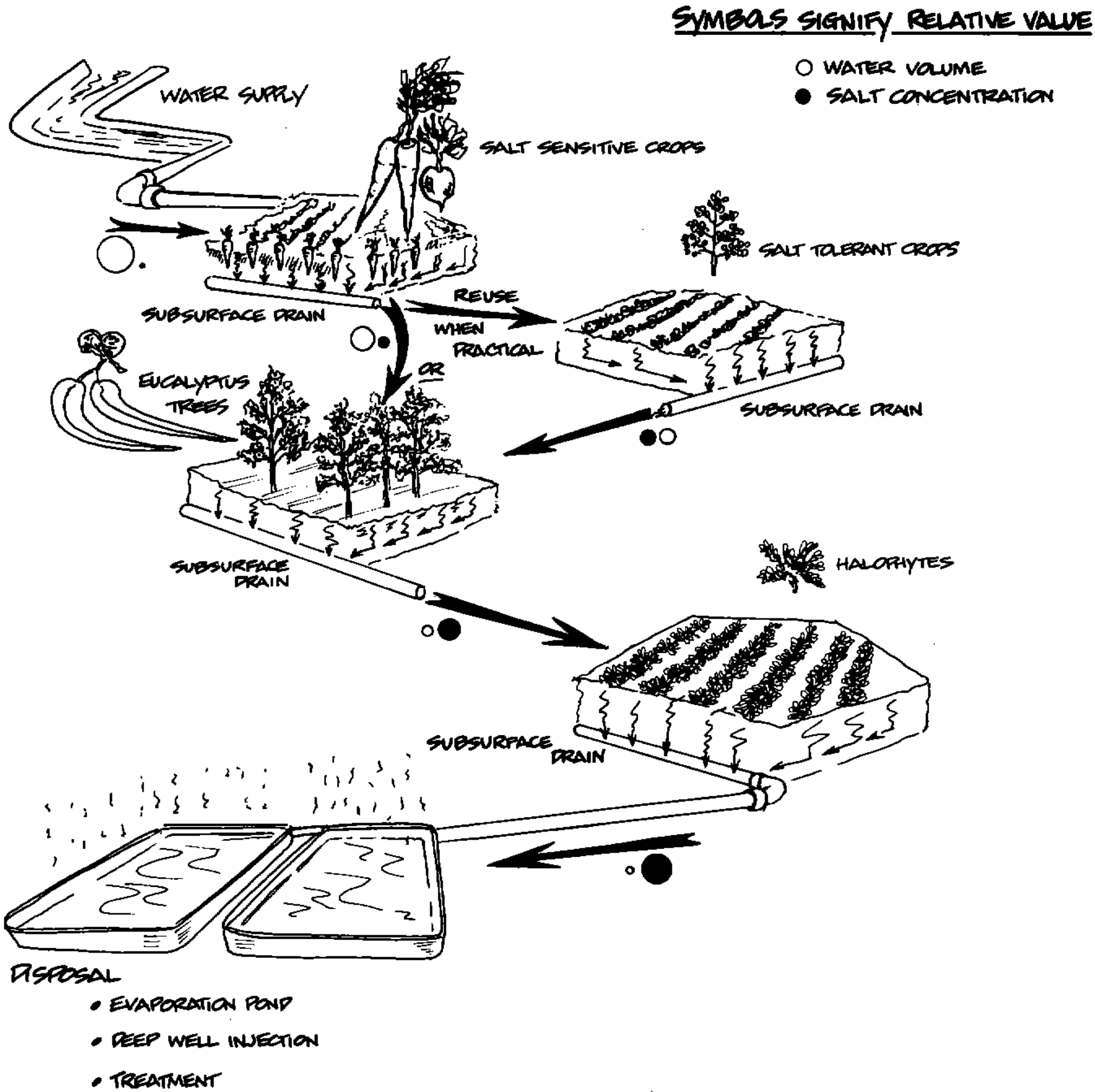
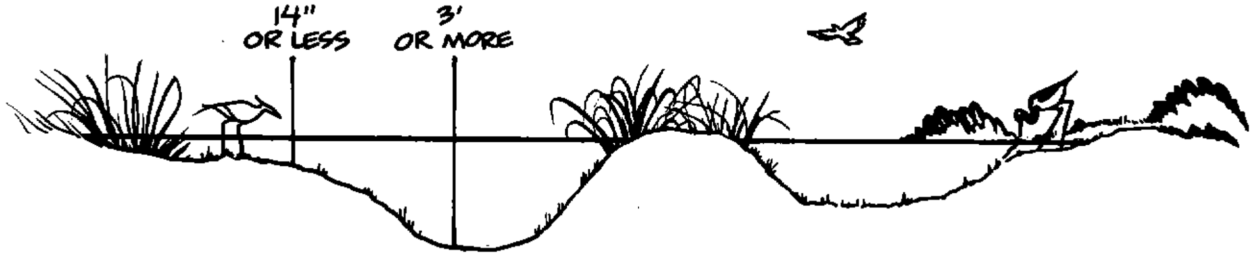
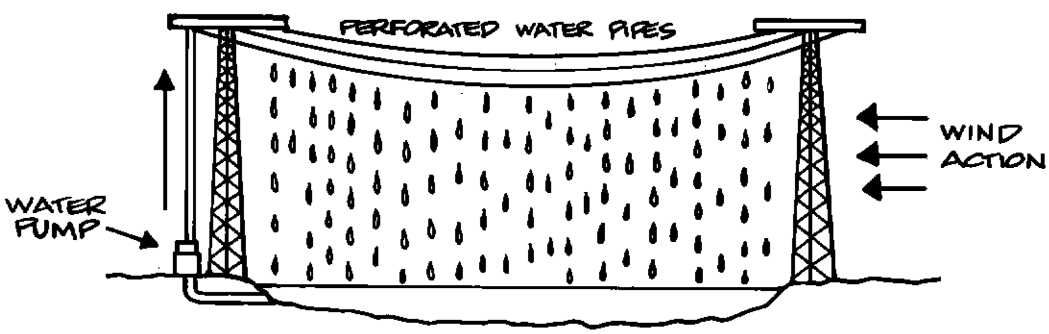


Figure 20. POND CONFIGURATIONS

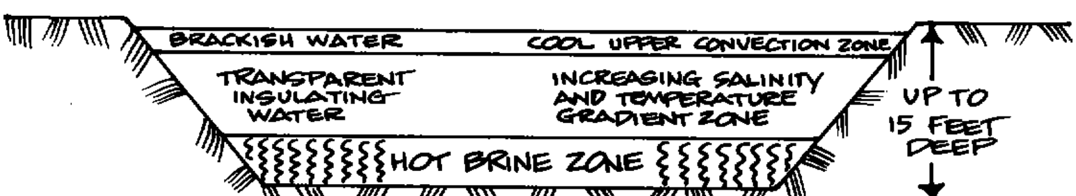
"STANDARD" EVAPORATION POND (2ppb TO 50ppb SELENIUM)



"NONTOXIC" EVAPORATION POND (< 2ppb SELENIUM)

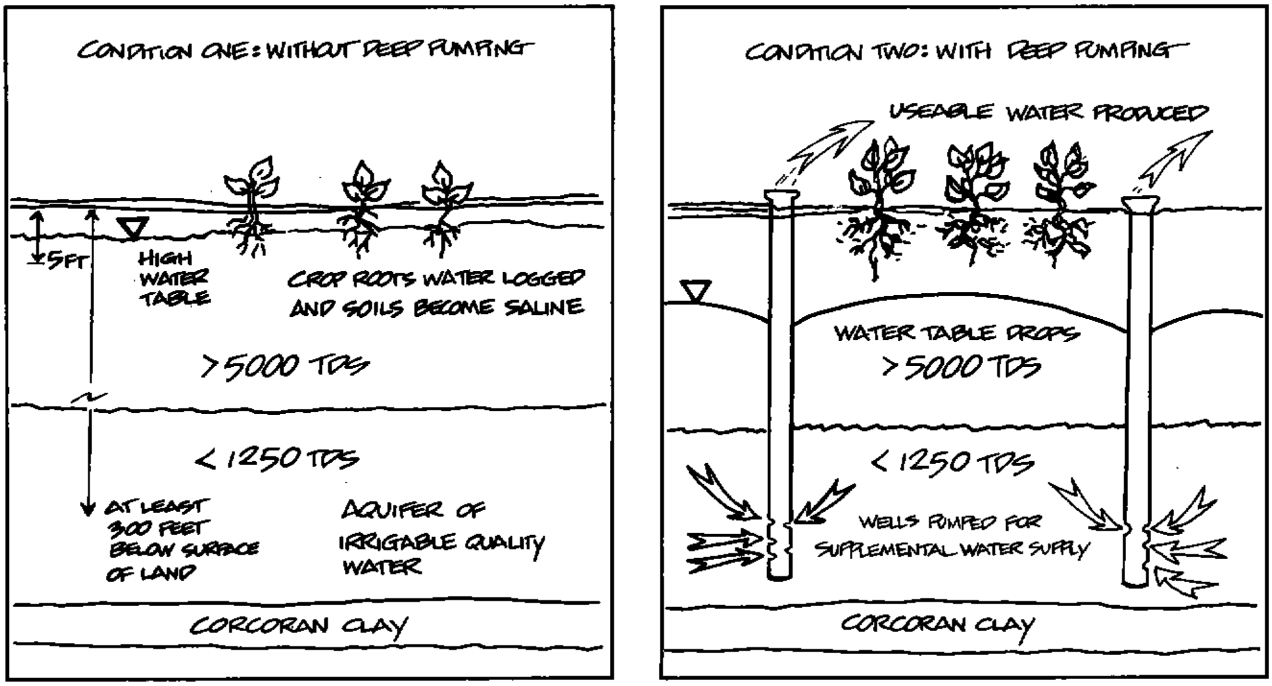


ACCELERATED RATE EVAPORATION POND



SOLAR POND

Figure 21. THE CONCEPT OF GROUND-WATER MANAGEMENT



The major benefit from the reuse strategy is the reduction of drainage-water volume. Volume could be reduced as much as 80 to 95 percent, depending on the crops, soils, and management of the system. A reduction in drainage-water volume translates to lower cost in final drainage-water management.

Ground-Water Management

The concept of ground-water management is to pump water, generally for irrigation, from the semiconfined aquifer above the Corcoran Clay to lower near-surface saline water tables (illustrated in Figure 21) and create a hydrologic balance that will keep the shallow water table below the crop root zone. In an unplanned manner, this strategy is currently being applied, to a minor extent, in the drainage problem area because some 2 million acre-feet of ground water is extracted annually from westside aquifers to supplement surface-water supplies. Although most of the pumping is from below the Corcoran Clay, the stress on the hydrologic system helps alleviate the subsurface drainage problem by providing storage space for deep percolation.

In this strategy, the ground water extracted would be in addition to present extractions, and would be designed specifically for each drainage problem area in which it was applicable. Wells would be perforated to produce water only from selected zones of the semiconfined aquifer. This method would be technically feasible only if all the following conditions existed in the subsurface aquifers under the drainage problem area: (1) Adequate vertical hydraulic interconnection between the deep aquifer and the waterlogged surface lands (not applicable to the Tulare lakebeds where thick clays are present); (2) a sufficient volume of water in the deep aquifer to allow withdrawal for a reasonable period of time (for example, 20 years); and (3) a production (from the well) water quality of less than 1,250 ppm TDS, so it may be used for agricultural irrigation. Reconnaissance-level geohydrologic investigations indicate that these conditions probably exist beneath those parts of drainage problem areas shown in Figure 12.

Several aspects of this strategy need to be recognized as potentially limiting its overall feasibility, even though the controlled pumping that would occur under the strategy could be an improvement over existing pumping conditions. First, the periods during which wells must be pumped to lower the water table to the required depth and the period in which they are pumped to supply water for irrigation or other beneficial uses may not correspond. Second, the application of this alternative might be viewed as a planned degradation of ground water. This interpretation might be reached, even though the present extent of ground-water pumping produces a regional hydraulic stress that is causing water passing the root zone to move downward at an annual rate of 1 to 3 feet vertically, transporting with it accumulated salt, boron, selenium, and other substances. Third, if this alternative were to be economically feasible, the aquifer must be capable of producing water suitable for beneficial uses for at least 20 years.

Although recent study has removed considerable uncertainties (Schmidt, 1988 and 1989; Quinn, 1990; CH_2M Hill, 1990; Phillips, 1990), an additional significant limiting factor is the continuing lack of adequate geohydrologic information on ground-water systems in some parts of the drainage problem area.

Land Retirement

The essential strategy of land retirement is to stop irrigating lands with poor drainage characteristics beneath which now lies shallow ground water so contaminated with selenium (and other substances) that drainage would be extremely difficult and the water produced would be costly to manage. Hydrologic investigations (Gilliom, et al., 1989b) indicate that, if a substantial land area (say, +5,000 acres) were retired from irrigation, the shallow water table beneath those lands would drop. To some extent, instead of contributing to their contamination, the dewatered area beneath the retired lands would then become a sink to receive some contaminated water from adjacent lands. Figure 22 illustrates how land retirement would lower ground-water levels.

The feasibility of this strategy hinges on the existence of shallow ground-water areas in which concentrations of selenium are much greater than those of surrounding areas. Figure 23 shows areas in which selenium concentrations in shallow ground water are more than 50 and 200 parts per billion. Areas over 200 parts per billion are considered to be "hot spots" and special candidates for retirement. The feasibility of land retirement also may depend on the existence of compensating benefits in the form of overall reduced costs of handling the drainage problem regionally, or in economic return to landowners from the sale or lease of the water supply no longer used for irrigation.

A related aspect of land retirement is that it could be considered a land reserve and, if at some future time, the problem necessitating retirement were to be resolved, the land could be used again for irrigated agriculture.

Figure 22. THE CONCEPT OF LAND RETIREMENT

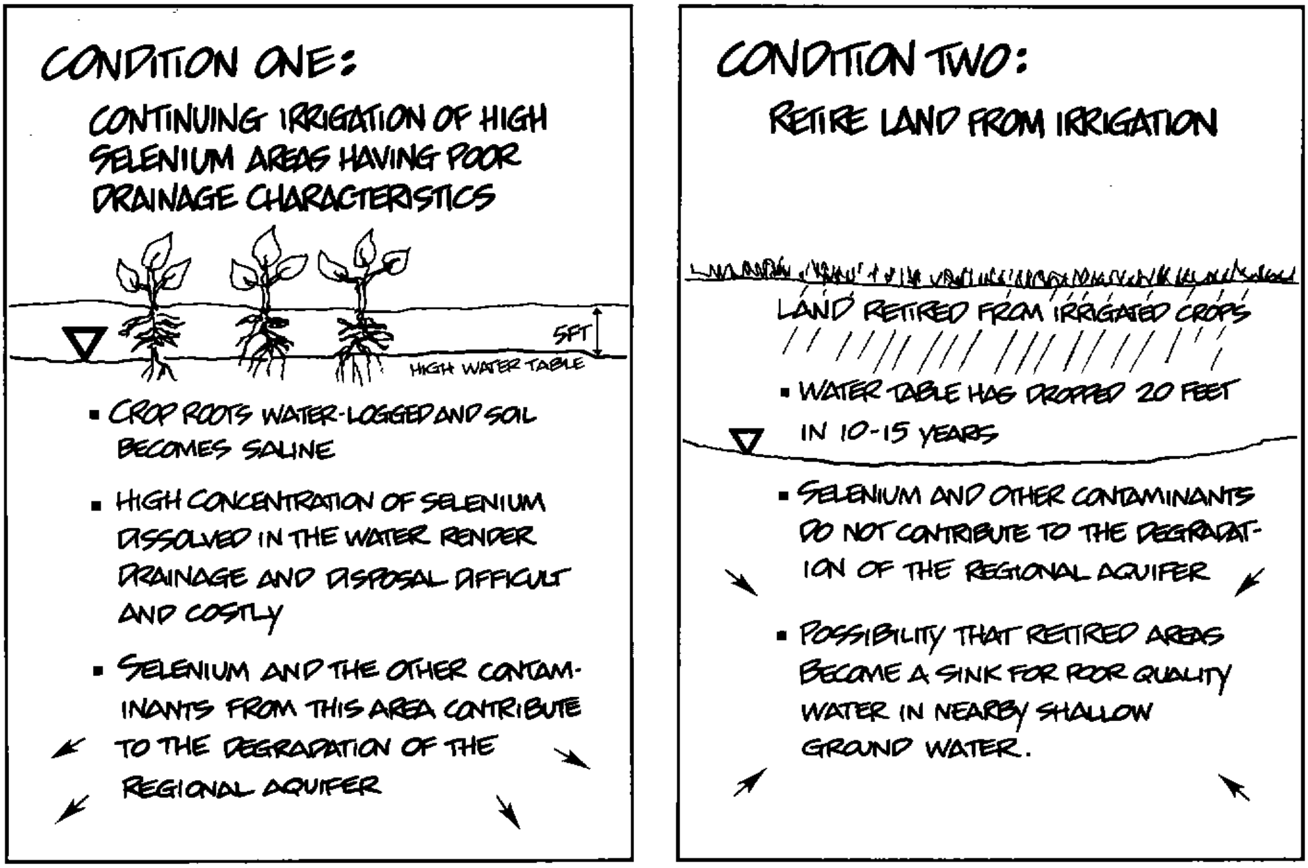
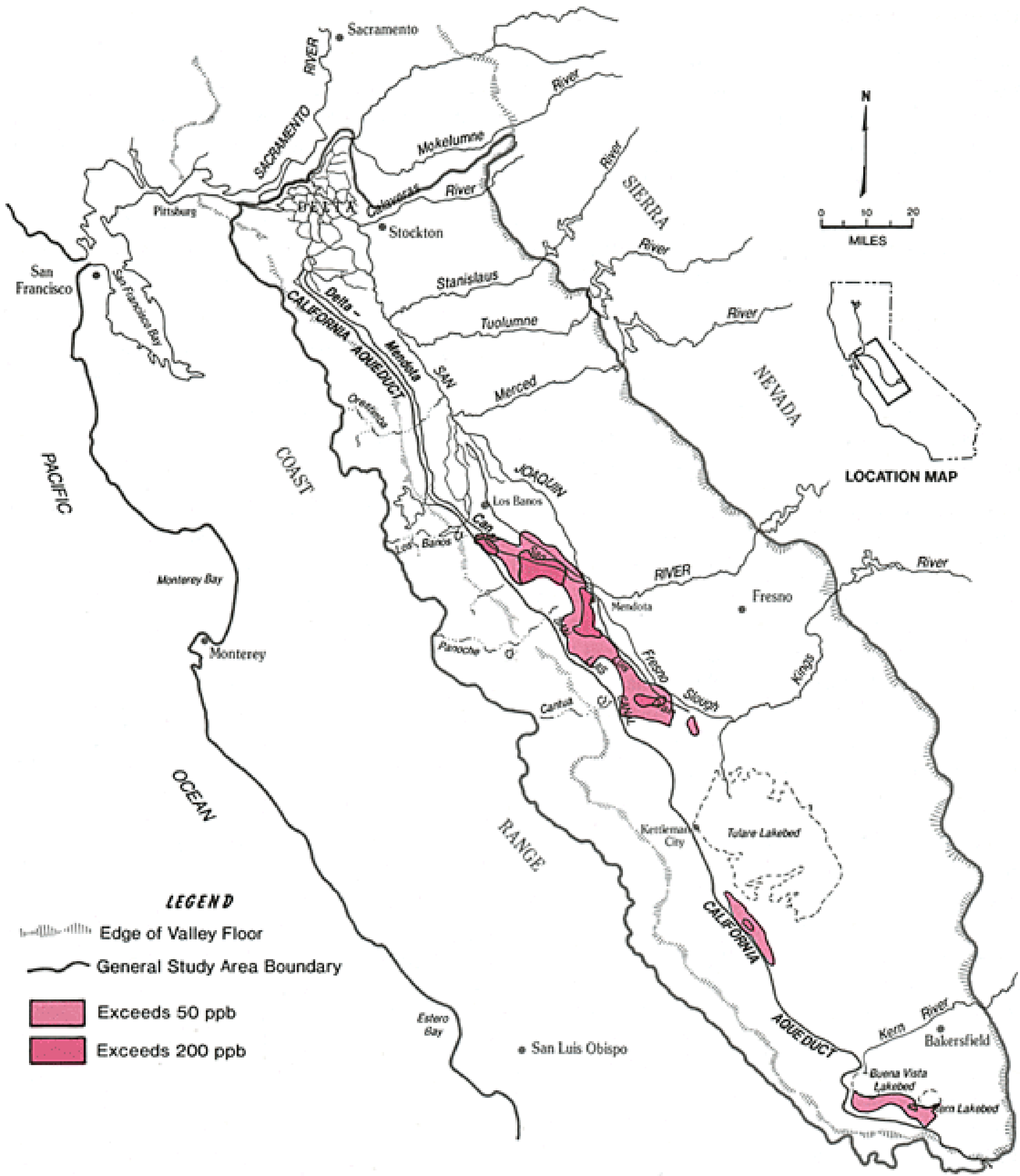


Figure 23

AREAS OF HIGHEST OBSERVED SELENIUM CONCENTRATIONS IN SHALLOW GROUND WATER



Description of Alternatives

The following alternatives are analyzed and evaluated to subarea scope and detail.

Northern Subarea

Alternatives for problem water reduction were not prepared for the Northern Subarea because two factors that tend to motivate major changes in management of drainage problems are largely missing in this part of the valley. First, the shallow ground water is of relatively good quality and low in concentrations of dissolved gypsum, a substance that contributes greatly to problems of westside salinization of soil and ground water (D.G. Swain, 1990).

Second, growers in the Northern Subarea are solving their drainage problems by draining their land and discharging about 20,000 acre-feet per year to the San Joaquin River. If water-quality objectives on the river do not change materially, growers would likely continue discharging to the river.

In addition to controlled subsurface drainage water, the San Joaquin River also receives about 100,000 acre-feet of ground water seepage annually from the Northern Subarea (CH_2M Hill, 1988), an unknown portion of which is related to irrigation water application. Because of the large volume, this flow contributes about 25 percent of the annual salt load flowing into the San Joaquin River at Vernalis, primarily during low flows.

Nishimura and Baughman (1989) have considered this phenomenon and remedial actions that might be both possible and necessary if more strict salt objectives were set for the San Joaquin River. One of the concepts mentioned prominently is a line of shallow wells that would be pumped during high river flows to evacuate the shallow ground water and create additional storage space for drainage water that would otherwise seep into the river during low-flow periods. Hydraulic and engineering studies conducted by the U.S. Bureau of Reclamation were reviewed by D.G. Swain (1990), who concludes that the concept of seasonal evacuation to halt the seepage (which could pose a problem during low flows) would not be effective because the San Joaquin River lacks the capacity to assimilate salt in most high-flow seasons. There would simply be too few opportunities to pump the interceptor wells because of the limited number of days in which the river has assimilitative capacity.

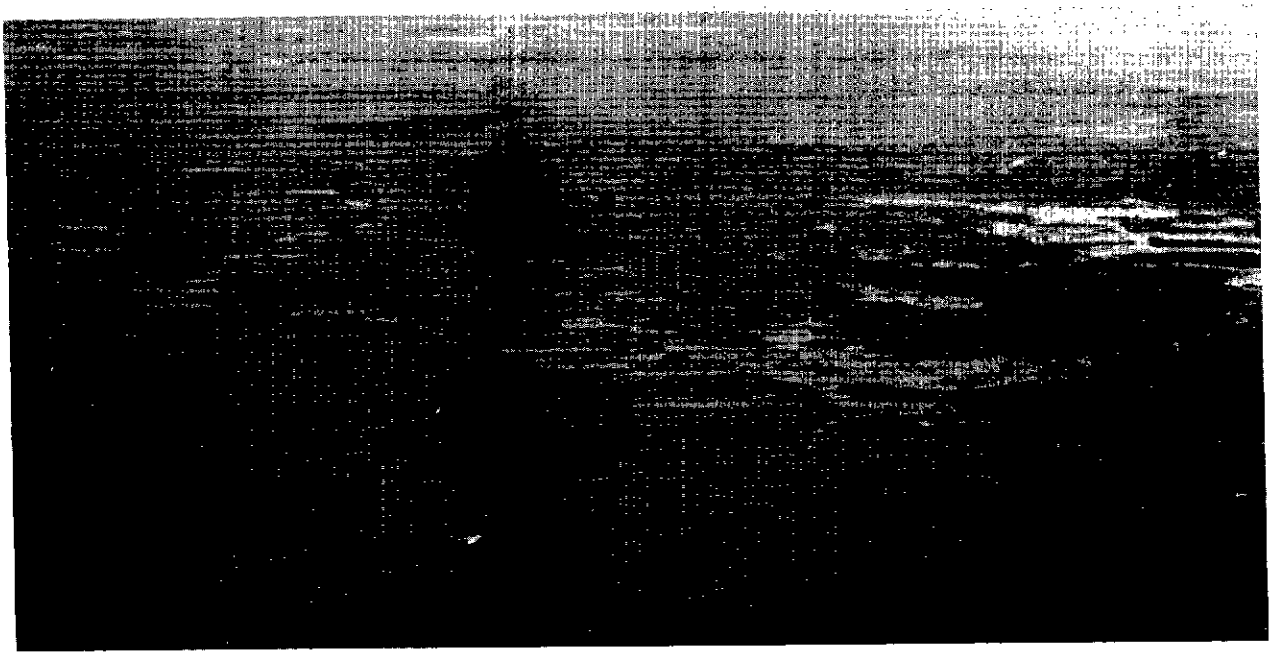
If measures were to be adopted within the subarea to lower the shallow water table adjacent to the San Joaquin River, these could reduce some of the salt load to the river because more salt would be stored in ground water. Two measures that are technically available are: (1) Improving on-farm water application to reduce deep percolation to ground water, and (2) changing the present pattern of surface- and ground-water use to greatly increase the volume of ground water extracted. Presently, only an estimated 30,000 acre-feet per year are pumped from the combined semiconfined and confined aquifers. (In the Northern Subarea, the aquifers are highly interconnected through gravel-packed and multiple-zone wells.) At present, about 94 percent of the agricultural water supply in the Northern Subarea is obtained from the combined sources of the San Joaquin River and the Delta-Mendota Canal. Substituting ground water pumped from below the irrigated area for a portion of this imported surface water would lower the water table and reduce seepage to the San Joaquin River. However, the subsurface drainage that would be discharged to the river would become more saline.

Grasslands Subarea

Figure 24 shows how various options would be combined to reduce problem water in the three planning alternatives. When read horizontally, the graphs show the effect on each option resulting from a shift from Level A to Level B performance standards. When read vertically, they show the effect on each option as the emphasis is changed from source control to ground-water management to land retirement. (Graphs are provided for this purpose in each subarea that follows.) Each Grasslands planning alternative includes the continued use of the San Joaquin River for disposal of some drainage water, although volumes would be reduced 15 to 20 percent under Level B selenium criteria, compared to the existing Level A criteria.

Table 18 shows major features of Grasslands Subarea planning alternatives. Under the alternatives emphasizing source control, the maximum water conservation from source control increases from about 30,000 acre-feet per year in 2000 to 50,000 acre-feet per year in 2040. Source control, featuring available water conservation technologies (such as shortening furrows and using a tailwater return system), is included only in water quality zones A and B (Figure 18), where it would reduce the volume of problem water by 30 to 40 percent, depending upon the criteria. Source control would not be applied in water quality zone C and 50 percent of Zone B (where there are some problems with waterlogging) because that drainage water is considered reusable for irrigating, managing wetlands, and/or increasing flow and improving quality of the San Joaquin River.

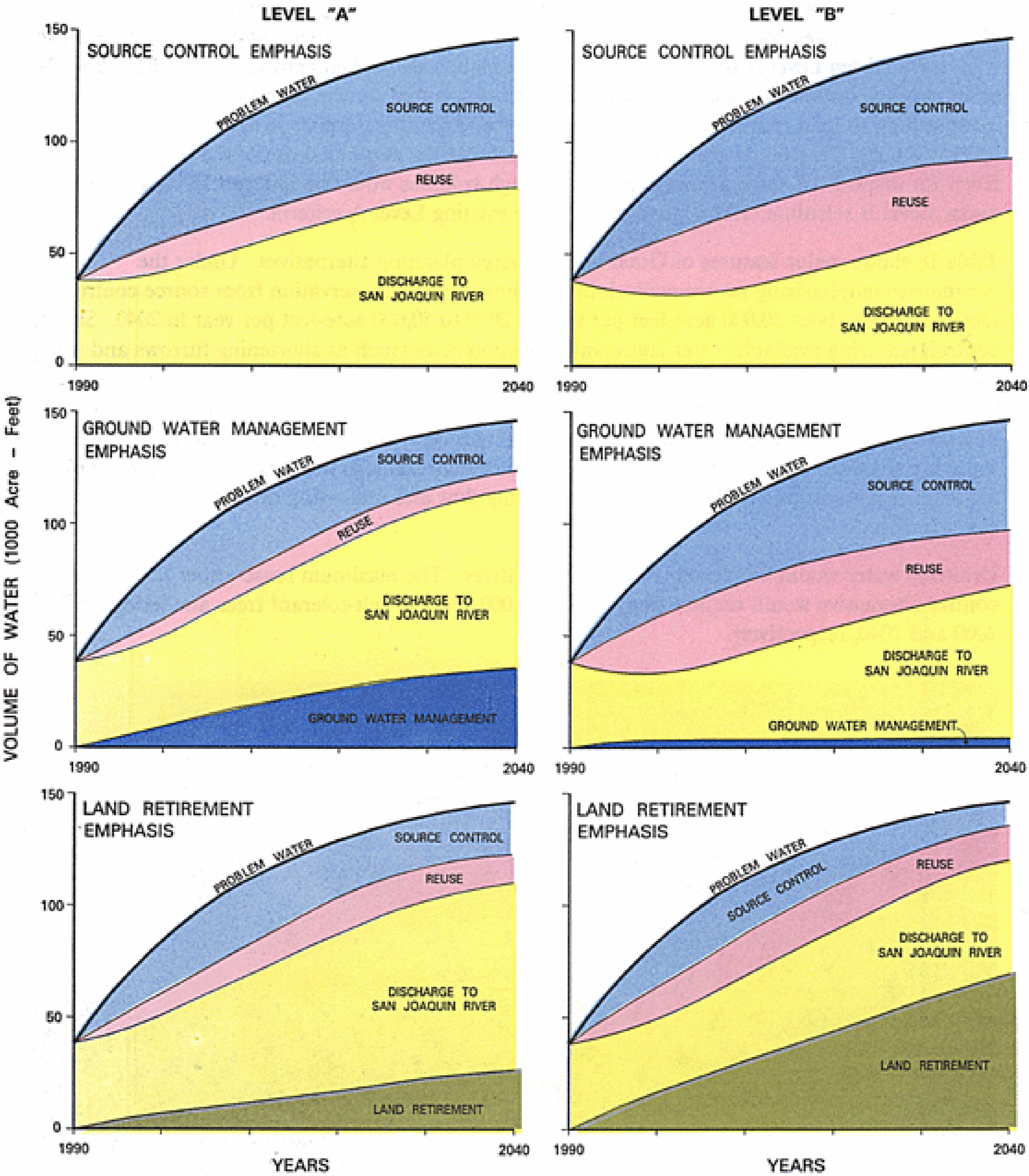
Drainage water would be reused under all alternatives. The maximum reuse under the source control alternative would require from 3,000 to 6,000 acres of salt-tolerant trees and halophytes by 2000 and 2040, respectively.



Wetlands in the Grasslands Subarea, which are laced with waterways, are flooded during the fall and winter waterfowl migration season.

Figure 24

PROBLEM WATER REDUCTION
GRASSLANDS SUBAREA



NOTE: Actions that reduce problem water less than 5000 acre-feet annually are not shown, but are discussed in the text.

Table 18. MAJOR FEATURES OF GRASSLANDS SUBAREA PLANNING ALTERNATIVES

In 1,000s

Performance Level and Plan Emphasis	Shallow Ground Water Area[1] Acres	Land Affected[2] Acres	Problem Water Volume[3] Acre-feet	Conserved-Water[4] Acre-feet	Land Reusing Drainage[5] Acres	Land Retired[6] Acres	Land Overlying GW Pumping[7] Acres	Area of Existing Evaporation Ponds Acres	Area of New Evaporation Ponds Acres
A-2000									
Source Control	218.0	116.0	86.5	30.1	3.1	0.0	0.6	0.1	0.0
Ground Water Management	218.0	116.0	86.5	29.4	1.6	1.9	8.9	0.1	0.0
Land Retirement	218.0	116.0	86.5	26.4	2.1	10.7	0.7	0.1	0.0
A-2040									
Source Control	218.0	196.0	147.0	53.6	3.1	0.0	0.6	0.1	0.0
Ground Water Management	218.0	196.0	147.0	23.8	2.3	0.0	60.8	0.1	0.0
Land Retirement	218.0	196.0	147.0	26.6	2.8	32.3	0.8	0.1	0.0
B-2000									
Source Control	218.0	116.0	86.5	30.1	5.4	0.0	1.2	0.1	0.0
Ground Water Management	218.0	116.0	86.5	30.1	5.4	0.0	1.2	0.1	0.0
Land Retirement	218.0	116.0	86.5	22.1	3.7	23.0	0.2	0.1	0.0
B-2040									
Source Control	218.0	196.0	147.0	53.6	5.8	0.0	1.3	0.1	0.0
Ground Water Management	218.0	196.0	147.0	53.6	5.8	0.0	1.3	0.1	0.0
Land Retirement	218.0	196.0	147.0	13.8	3.0	70.2	0.7	0.0	0.0

1 Irrigated land area with a depth to shallow ground water less than 5 feet.
2 That portion of shallow water areas drained.
3 The forecasted annual drainage volume that must be managed; drained land x 0.75 acre-feet per acre of deep percolation
4 Water supply conserved by on-farm water conservation measures and management practices on problem water lands.
5 Acreage in trees and halophytes.
6 Lands targeted for retirement from irrigated agriculture (excluding lands designated for other uses).
7 Land area where pumping from the semiconfined aquifer is used to lower shallow water table below crop root zone.

Because of geohydrologic conditions, opportunities for deep pumping of the semiconfined aquifer are limited to about 60,000 acres, largely in problem zone A. No new evaporation ponds would be included with any alternative.

Under the land retirement alternative, retirement of irrigated land would be greater under Level B criteria and would increase from about 23,000 to 70,000 acres between 2000 and 2040.

Westlands Subarea

Figure 25 shows how various options would be combined to reduce problem water in the three planning alternatives. Each planning alternative places major reliance on source control for reducing problem water — up to a maximum of about 60 percent in 2040, under the source control alternative.

Table 19 shows major features of Westlands Subarea planning alternatives. The maximum water conservation from source control would be 38,000 acre-feet annually by 2000, and 92,000 acre-feet annually by 2040, under either performance Levels A or B.

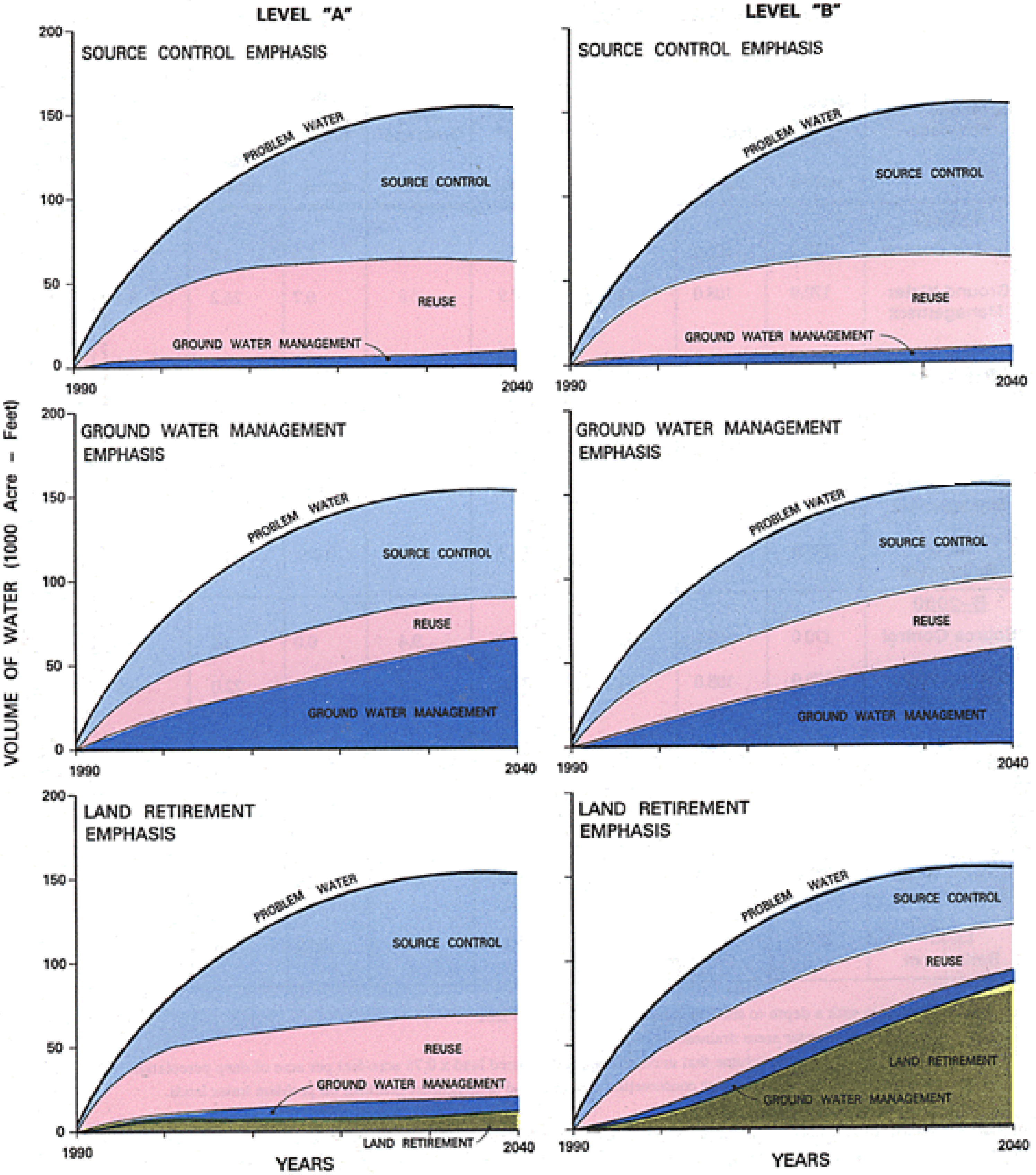
Reuse of drainage water is a major feature of all alternatives for the Westlands Subarea. Under maximum reuse, 9,000 to 14,000 acres of trees and halophytes would be used to reduce problem water volume in 2000 and 2040, respectively.

Subsurface physical conditions most strongly favor deep pumping from the semiconfined aquifer to lower shallow ground-water levels in water quality zones C and D (Figure 18). Level A criteria, ground-water management alternative, shows the area of maximum pumping would increase from about 26,000 acres in 2000 to 107,000 acres in 2040.

Under Level B criteria for the land retirement alternative (all shallow ground-water areas above 50 ppb selenium), 12,000 acres would be retired from irrigation by 2000 and 107,000 acres by 2040. In contrast to areas suitable for ground-water management in the southeastern part of Westlands Subarea, areas that fit the criteria for land retirement are located primarily in the northern part. No new evaporation ponds would be included under any alternative.

Figure 25

PROBLEM WATER REDUCTION
WESTLANDS SUBAREA



NOTE: Actions that reduce problem water less than 5000 acre-feet annually are not shown, but are discussed in the text.

Table 19. MAJOR FEATURES OF WESTLANDS SUBAREA PLANNING ALTERNATIVES

In 1,000s

Performance Level and Plan Emphasis	Shallow Ground Water Area[1] Acres	Land Affected[2] Acres	Problem Water Volume[3] Acre-feet	Conserved-Water[4] Acre-feet	Land Reusing Drainage[5] Acres	Land Retired[6] Acres	Land Overlying GW Pumping[7] Acres	Area of Existing Evaporation Ponds Acres	Area of New Evaporation Ponds Acres
A-2000									
Source Control	170.0	108.0	81.1	37.9	9.4	0.0	3.5	0.1	0.0
Ground Water Management	170.0	108.0	81.1	37.9	5.8	0.7	26.2	0.1	0.0
Land Retirement	170.0	108.0	81.1	34.4	8.4	10.2	3.1	0.1	0.0
A-2040									
Source Control	227.0	205.0	153.9	92.4	13.8	0.0	5.1	0.5	0.0
Ground Water Management	227.0	205.0	153.9	62.4	7.8	0.0	106.9	0.5	0.0
Land Retirement	227.0	205.0	153.9	85.7	12.5	14.5	4.6	0.3	0.0
B-2000									
Source Control	170.0	108.0	81.1	37.9	9.4	0.0	3.5	0.3	0.0
Ground Water Management	170.0	108.0	81.1	37.9	6.2	0.0	22.0	0.5	0.0
Land Retirement	170.0	108.0	81.1	33.9	8.5	11.5	2.7	0.3	0.0
B-2040									
Source Control	227.0	205.0	153.9	92.4	13.6	0.0	5.7	0.1	0.0
Ground Water Management	227.0	205.0	153.9	56.6	10.7	0.0	97.8	0.5	0.0
Land Retirement	227.0	205.0	153.9	39.9	7.2	106.9	2.0	0.0	0.0

1 Irrigated land area with a depth to shallow ground water less than 5 feet.
2 That portion of shallow water areas drained.
3 The forecasted annual drainage volume that must be managed; drained land x 0.75 acre-feet per acre of deep percolation.
4 Water supply conserved by on-farm water conservation measures and management practices on problem water lands.
5 Acreage in trees and halophytes.
6 Lands targeted for retirement from irrigated agriculture (excluding lands designated for other uses).
7 Land area where pumping from the semiconfined aquifer is used to lower shallow water table below crop root zone.

Tulare Subarea

Figure 26 shows how various options would be combined in the Tulare Subarea to reduce problem water. Table 20 shows major features of Tulare Subarea planning alternatives. All plans include major reliance on source control for reducing problem water, up to a maximum of about 60 percent in 2040 under the source control alternative. The maximum water conservation through source control would be 44,000 acre-feet annually by 2000 and 156,000 acre-feet annually by 2040, under the source control alternative.

Reuse of drainage water is a major feature of the alternatives presented for the Tulare Subarea. Under the maximum reuse option, from 11,000 to 23,000 acres of trees and halophytes would be used in 2000 and 2040, respectively.

Conditions favorable for deep pumping of the semiconfined aquifer occur largely in areas influenced by the Kings River Delta: water quality zones A, D, and E (Figure 18). The planning criteria would allow pumping under a maximum of about 20,000 acres in 2000 and 135,000 acres in 2040. Ground-water management or evaporation ponds may be used in zone E, where drainage water is generally very low in dissolved selenium. No new evaporation ponds are included in any alternative. Further study may reveal that evaporation ponds in the South Kings River Delta (zone E) would be bird-safe because of low contaminant concentrations in drainage water.

No shallow ground water in the Tulare Subarea is known to be high enough in selenium concentration to exceed the 200 ppb planning criterion for land retirement. Alternatives emphasizing land retirement are included, but they are almost identical to the source control alternatives.

Kern Subarea

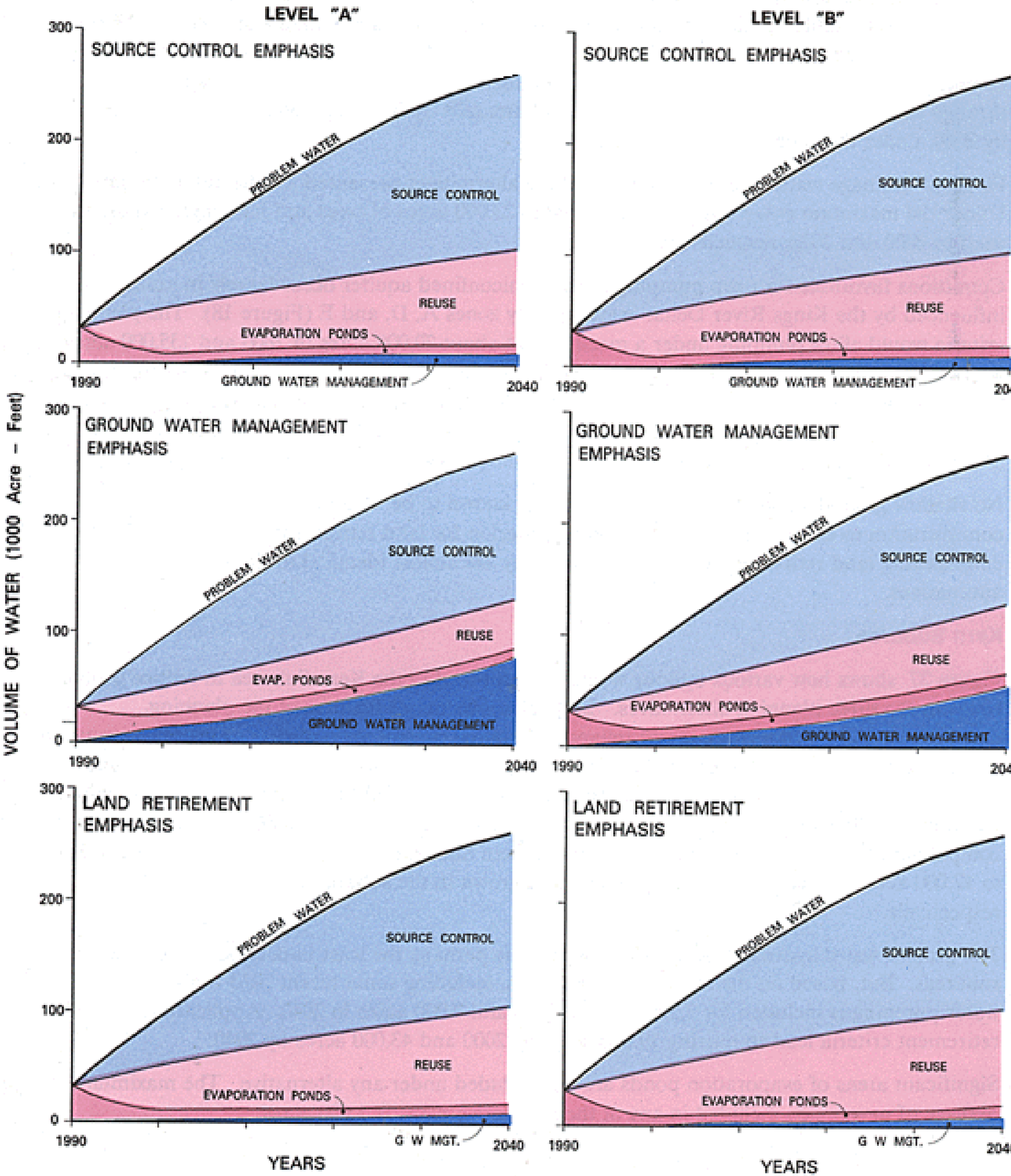
Figure 27 shows how various options would be combined in the Kern Subarea to reduce problem water in the three planning alternatives. Table 21 shows major features of the planning alternatives. All plans include major reliance on source control for reducing problem water, up to a maximum of about 55 percent in 2040, under the source control alternative. The maximum water conservation that would occur through source control would be 21,000 acre-feet annually by 2000 and 68,000 acre-feet annually by 2040, under several alternatives. Reuse is also an important component of the alternatives presented for the Kern Subarea. Under maximum reuse, from 6,000 to 12,000 acres of trees and halophytes would be grown in the subarea in 2000 and 2040, respectively.

The ground water hydrology of the Kern Subarea is perhaps the least understood of all the subareas. But, based on the available information, including some recent field work, ground water pumping is included for 1,500 acres in 2000 and 7,000 acres in 2040. Application of land retirement criteria lead to retiring 19,000 acres by 2000 and 43,000 acres by 2040.

Significant areas of evaporation ponds are not included under any alternative. The maximum acreage of new ponds included in any of the alternative plans is 1,600 acres.

Figure 26

PROBLEM WATER REDUCTION
TULARE SUBAREA



NOTE: Actions that reduce problem water less than 5000 acre-feet annually are not shown, but are discussed in the text.

Table 20. MAJOR FEATURES OF TULARE SUBAREA PLANNING ALTERNATIVES

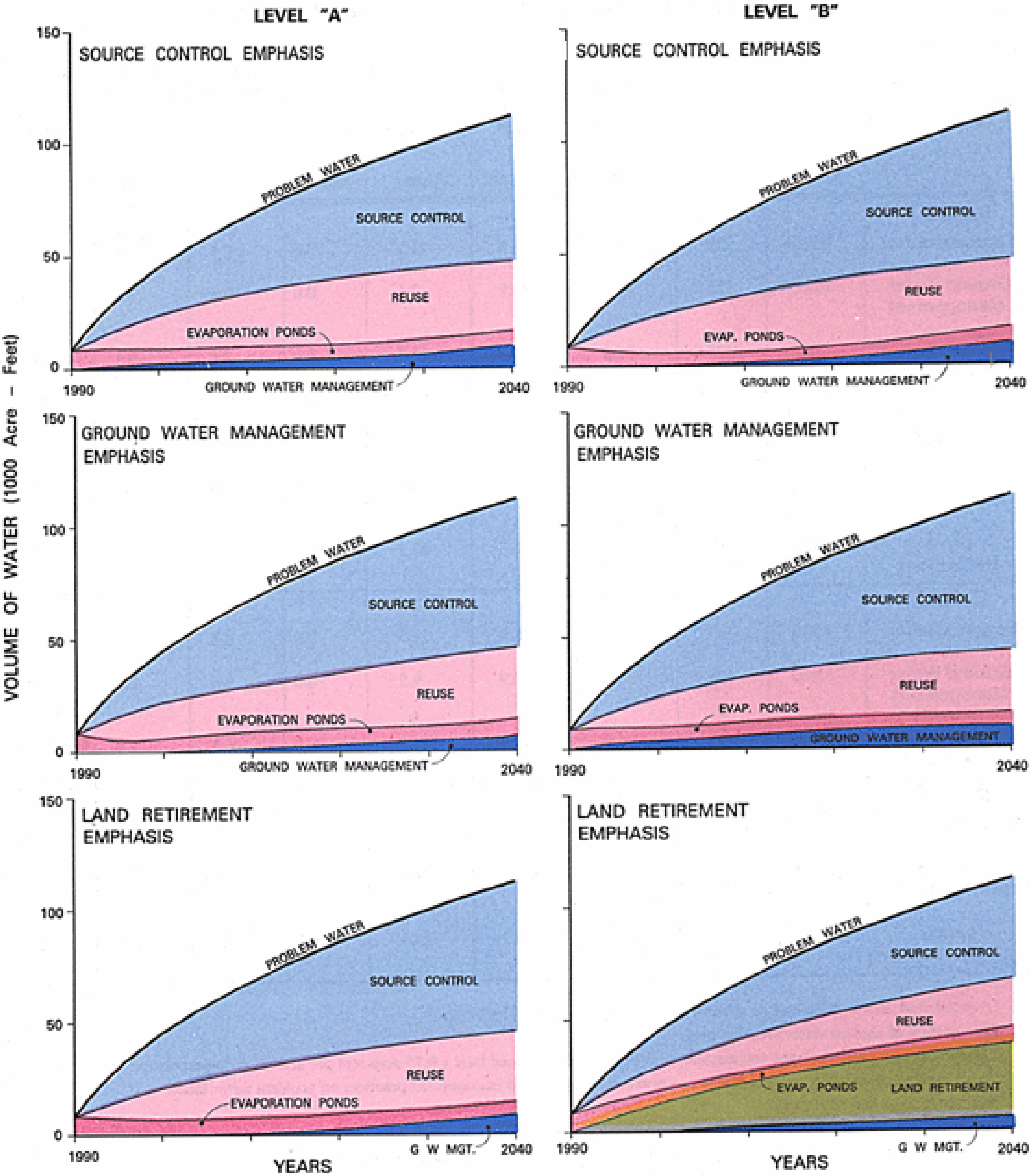
In 1,000s

Performance Level and Plan Emphasis	Shallow Ground Water Area[1] Acres	Land Affected[2] Acres	Problem Water Volume[3] Acre-feet	Conserved-Water[4] Acre-feet	Land Reusing Drainage[5] Acres	Land Retired[6] Acres	Land Overlying GW Pumping[7] Acres	Area of Existing Evaporation Ponds Acres	Area of New Evaporation Ponds Acres
A-2000									
Source Control	359.0	125.0	94.0	43.9	11.3	0.0	0.4	2.4	0.0
Ground Water Management	359.0	125.0	94.0	43.9	7.4	0.0	19.3	2.5	0.0
Land Retirement	359.0	125.0	94.0	43.9	10.7	0.0	1.4	2.4	0.0
A-2040									
Source Control	387.0	347.0	260.4	156.3	23.3	0.0	7.1	2.0	0.0
Ground Water Management	387.0	347.0	260.4	132.5	12.6	0.0	135.4	2.0	0.0
Land Retirement	387.0	347.0	260.4	156.3	23.3	0.0	6.7	2.0	0.0
B-2000									
Source Control	359.0	125.0	94.0	43.9	11.3	0.0	0.8	2.4	0.0
Ground Water Management	359.0	125.0	94.0	43.9	9.5	0.0	8.4	2.4	0.0
Land Retirement	359.0	125.0	94.0	43.9	11.3	0.0	0.4	2.4	0.0
B-2040									
Source Control	387.0	347.0	260.4	156.3	23.3	0.0	5.7	2.5	0.0
Ground Water Management	387.0	347.0	260.4	132.5	17.0	0.0	94.5	2.5	0.0
Land Retirement	387.0	347.0	260.4	156.3	23.3	0.0	5.7	2.5	0.0

1 Irrigated land area with a depth to shallow ground water less than 5 feet.
2 That portion of shallow water areas drained.
3 The forecasted annual drainage volume that must be managed; drained land x 0.75 acre-feet per acre of deep percolation
4 Water supply conserved by on-farm water conservation measures and management practices on problem water lands.
5 Acreage in trees and halophytes.
6 Lands targeted for retirement from irrigated agriculture (excluding lands designated for other uses).
7 Land area where pumping from the semiconfined aquifer is used to lower shallow water table below crop root zone.

Figure 27

PROBLEM WATER REDUCTION
KERN SUBAREA



NOTE: Actions that reduce problem water less than 5000 acre-feet annually are not shown, but are discussed in the text.

Table 21. MAJOR FEATURES OF KERN SUBAREA PLANNING ALTERNATIVES

In 1,000s

Performance Level and Plan Emphasis	Shallow Ground Water Area[1] Acres	Land Affected[2] Acres	Problem Water Volume[3] Acre-feet	Conserved-Water[4] Acre-feet	Land Reusing Drainage[5] Acres	Land Retired[6] Acres	Land Overlying GW Pumping[7] Acres	Area of Existing Evaporation Ponds Acres	Area of New Evaporation Ponds Acres
A-2000									
Source Control	110.0	61.0	45.8	21.4	6.0	0.0	2.6	1.3	0.1
Ground Water Management	110.0	61.0	45.8	21.4	6.0	3.2	2.5	1.3	0.0
Land Retirement	110.0	61.0	45.8	20.2	5.7	3.2	2.5	1.2	0.1
A-2040									
Source Control	167.0	150.0	112.6	67.5	11.7	0.0	6.9	1.5	0.0
Ground Water Management	167.0	150.0	112.6	67.6	11.2	0.0	6.9	1.6	0.0
Land Retirement	167.0	150.0	112.6	66.2	11.5	3.1	5.6	1.6	0.0
B-2000									
Source Control	110.0	61.0	45.8	21.4	6.0	0.0	2.6	1.2	0.1
Ground Water Management	110.0	61.0	45.8	21.4	6.0	0.0	2.6	1.3	0.0
Land Retirement	110.0	61.0	45.8	14.8	4.1	18.7	1.5	1.0	0.0
B-2040									
Source Control	167.0	150.0	112.6	67.6	11.2	0.0	6.7	1.6	0.0
Ground Water Management	167.0	150.0	112.6	67.6	11.2	0.0	6.9	1.6	0.0
Land Retirement	167.0	150.0	112.6	44.5	8.7	42.6	4.8	1.6	0.0

1 Irrigated land area with a depth to shallow ground water less than 5 feet.
2 That portion of shallow water areas drained.
3 The forecasted annual drainage volume that must be managed; drained land x 0.75 acre-feet per acre of deep percolation
4 Water supply conserved by on-farm water conservation measures and management practices on problem water lands.
5 Acreage in trees and halophytes.
6 Lands targeted for retirement from irrigated agriculture (excluding lands designated for other uses).
7 Land area where pumping from the semiconfined aquifer is used to lower shallow water table below crop root zone.

SUMMARY AND CONCLUSIONS FROM ANALYSES OF SUBAREA PLANNING ALTERNATIVES

Table 22 summarizes the major components of drainage management alternatives for the study area (the four subareas for which alternatives were prepared).

The alternatives were developed to show the effects of emphasizing different strategies for managing drainage water. The conclusions that follow are based on analysis of the alternatives and are used in formulating the recommended plan presented in Chapter 6:

- Few major differences exist among the six alternatives presented in each subarea, due primarily to the narrow ranges of choice actually available when physical constraints, present and likely environmental regulations, and costs are considered. The lack of difference is also due to the inclusion of source control and reuse in all alternatives. These options were included because they are available technologies that could be applied throughout the study area and because of their comparative cost advantage.

- The opportunity for discharge of drainage water to the San Joaquin River causes the Grasslands Subarea to differ considerably from other subareas.

- The planning alternatives show that the amount of water conserved by on-farm methods of drainage-water source control ranges from about 250,000 to 370,000 acre-feet annually by 2040. When land retirement and ground-water management are added to source control, the range of water conserved increases to 530,000 to 950,000 acre-feet annually by 2040. Water conserved by source control and ground-water management would benefit the water user, and values are taken to lower the costs of these options. It is assumed that at least 2.6 acre-feet per acre of water would be freed by land retirement, but no value is taken in this analysis because the value of the water is included in the market value of the irrigated lands to be purchased.

- The analyses show how specific alternatives serve certain objectives that could be considered auxiliary to the objective of all plans of the Drainage Program — solving the drainage water problem. For example, the objective of conserving water at least cost would be served best by maximizing the source control and reuse options. If minimizing risk from toxicants were the dominant objective, then the land retirement component should be maximized.

- A practical mix of drainage management options will not be found by formulating plans to adhere strictly to the criteria for performance Level A or performance Level B. However, analysis of alternatives formulated in that way provides a base for designing a plan that is more efficient than either Level A or B, or the future-without alternative.

- Because of the complexities of the interactive factors involved in solving the drainage problems and the many unknowns, only limited success has been achieved in modeling the natural and cultural features of the problem area. This has prevented asking "what-if" questions that could generate an infinite number of alternatives. Professional judgment, local experience, and public review will evidently continue to be the most important resources in developing a successful plan.

Table 22. MAJOR FEATURES OF STUDY AREA PLANNING ALTERNATIVES

In 1,000s

Performance Level and Plan Emphasis	Shallow Ground Water Area[1] Acres	Land Affected[2] Acres	Problem Water Volume[3] Acre-feet	Conserved-Water[4] Acre-feet	Land Reusing Drainage[5] Acres	Land Retired[6] Acres	Land Overlying GW Pumping[7] Acres	Area of Existing Evaporation Ponds Acres	Area of New Evaporation Ponds Acres
A-2000									
Source Control	857.0	410.0	307.4	133.3	29.8	0.0	7.1	4.2	0.1
Ground Water Management	857.0	410.0	307.4	132.4	20.8	5.8	56.9	4.4	0.0
Land Retirement	857.0	410.0	307.4	124.9	26.9	24.1	7.7	4.0	0.1
A-2040									
Source Control	999.0	898.0	673.9	369.9	51.7	0.0	19.7	4.1	0.1
Ground Water Management	999.0	898.0	673.9	286.3	33.9	0.0	310.0	4.2	0.01
Land Retirement	999.0	898.0	673.9	334.8	50.1	49.9	17.7	4.0	0.1
B-2000									
Source Control	857.0	410.0	307.4	133.3	32.1	0.0	8.1	4.0	0.1
Ground Water Management	857.0	410.0	307.4	133.3	27.1	0.0	34.2	4.3	0.0
Land Retirement	857.0	410.0	307.4	114.7	27.6	53.2	4.8	3.8	0.0
B-2040									
Source Control	999.0	898.0	673.9	369.9	53.9	0.0	19.4	4.3	0.1
Ground Water Management	999.0	898.0	673.9	310.3	44.7	0.0	200.5	4.7	0.1
Land Retirement	999.0	898.0	67.3	254.5	42.2	219.7	13.2	4.1	0.1

1 Irrigated land area with a depth to shallow ground water less than 5 feet.
2 That portion of shallow water areas drained.
3 The forecasted annual drainage volume that must be managed; drained land x 0.75 acre-feet per acre of deep percolation
4 Water supply conserved by on-farm water conservation measures and management practices on problem water lands.
5 Acreage in trees and halophytes.
6 Lands targeted for retirement from irrigated agriculture (excluding lands designated for other uses).
7 Land area where pumping from the semiconfined aquifer is used to lower shallow water table below crop root zone.